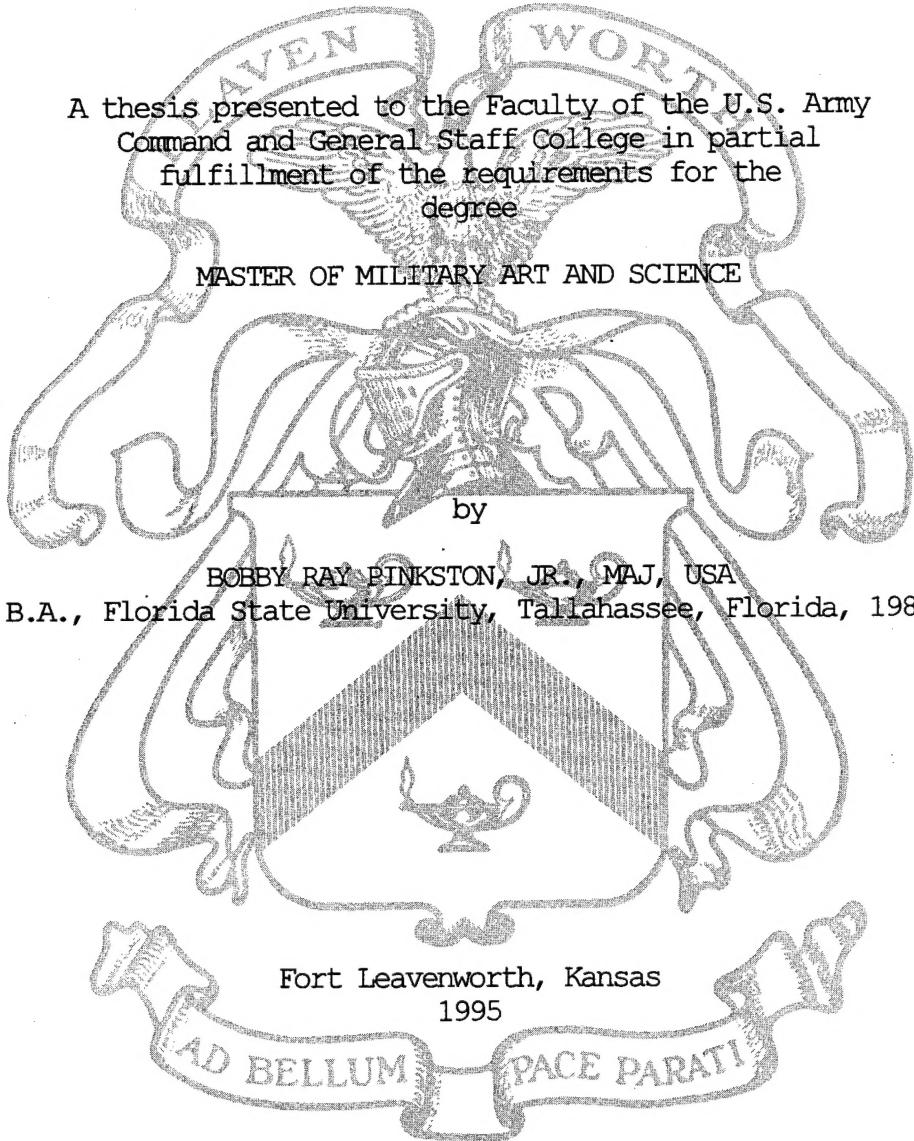


THE LOGISTICAL IMPLICATIONS OF THE PRUSSIAN USE OF RAILROADS
FOR STRATEGIC AND OPERATIONAL MOBILITY, 1857-1914



A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE

by

BOBBY RAY PINKSTON, JR., MAJ, USA
B.A., Florida State University, Tallahassee, Florida, 1983

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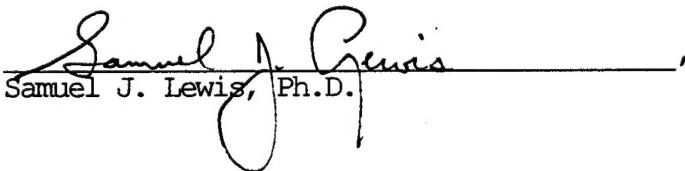
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ABSTRACT

THE LOGISTICAL IMPLICATIONS OF PRUSSIA'S USE OF RAILROADS FOR STRATEGIC AND OPERATIONAL MOBILITY, 1857-1914, by MAJ Bobby Ray Pinkston, Jr., USA, 78 pages.

This study investigates the impact that the use of railroads had on the general performance of the Prussian logistics system. Between 1857-1914 the Prussians continually expanded their use of railroads for the strategic and operational movement of soldiers and supplies. At the same time their tactical transportation system remained largely unchanged, primarily relying on horses and wagons.

This wide technological gap between the strategic/operational and the tactical modes of transportation was a source of continual logistical difficulty for the Prussians. Throughout the period the Prussian Army had great difficulty tactically distributing supplies delivered by the railroads.

This study explains how this situation developed, and what was its consequence. It highlights the problems that nations face when they develop one system to the exclusion of its supporting systems.

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B.R.P

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CHAPTER 1

BACKGROUND

Introduction

Mars must be fed, to paraphrase the title of a recently published book.¹ In addition to being fed, a war machine must be armed, repaired, mended, supplied, and moved about the battlefield. Such is the job of logistics. The challenge of providing soldiers and armies with what they need has always been a part of war. Nations devote enormous resources to maintaining their war machines. How a nation chooses to support its army can have profound consequences. Wars have been won and lost upon the ability of a nation to move and supply its army.

Just as armies are affected by logistics, so is logistics affected by its component operations. This study will examine the logistical consequences of a nation's decision to adopt a particular mode of transportation, in this case the Prussians and railroads. What this study plans to achieve is not only a better understanding of the logistical implications for Prussia, but a better understanding of logistical implications in general, and their meaning for present and future war planners.

Throughout history, nations have struggled to move their armies where needed and keep them supplied once they were there. This whole

operation requires tremendous effort, even though in concept logistics is simple. It requires identifying needs and developing procedures to satisfy those needs. In principle it is not difficult, however, as the famous Prussian Carl von Clausewitz reminded us, "Everything in war is very simple, but the simplest thing is difficult."² Nowhere is this more true than in logistics.

Like most states the Prussians struggled to move their army to where it was needed and keep it supplied once it was there. The Prussians developed several innovative concepts to help them overcome these problems. One of the most significant of these was the use of the railroads. The Prussians were not the first to develop railroads, yet between 1857-1914 the Prussians outpaced all other European nations in the military uses of railroads. The Prussians saw railroads as the key to rapid mobilization and the strategic movement of troops and matériel. The use of railroads was an important feature of all war plans. The efficient use of railroads gave the Prussians certain military advantages over their neighbors. At the same time, railroads placed certain limitations on the military and the nation that may not have been immediately obvious.

What was discovered was that while the Prussians made good use of the railroads, this did not significantly improve their logistics operations. There are many reasons for this, the primary one being that Prussia's real problem was not the strategic or operational distribution of supplies. Its real problem was the tactical distribution of supplies. For this it still relied on horses and wagons, just as it had for centuries. These proved to be unable to support modern armies with

the volume of supplies they required for combat operations. No matter how efficient the railroads were, they could not fill this tactical void. The remainder of this study will explore how this happened and what were it consequences for the Prussians.

Prussian War Planning and the Men Behind It

Helmuth von Moltke was appointed head of the Prussian Great General Staff (GGS) on 29 October 1857.³ At that time, the GGS was a tiny and not very well known section of the war ministry. Most officers serving in the Prussian Army were unfamiliar with its purpose and function. This situation would remain unchanged until the end of July 1866, when after six weeks of war the Prussian Army soundly defeated the army of the Austro-Hungarian Empire. The victory over Austria would raise the standing of Moltke and the GGS to a level of prominence, where it would remain until the end of the First World War.

Between 1857 and 1914 four men would serve as Chief of the GGS. In addition to Helmuth von Moltke (1857-1888), there were Alfred von Waldersee (1888-1891), Alfred von Schlieffen (1891-1906), and Helmuth von Moltke (the Younger) (1906-1914). These four men presided over the GGS during a period of profound change in warfare. These changes included the enlargement of the levee en masse and a large number of technological changes made possible by the industrial revolution, among the most important of these the development of the railroad.

Moltke immediately went about making several changes in the general staff and its war planning process. One of his first major undertakings was a draft document on the use of railroads for large

troop movements. What began as a draft document would end up 50 years later as the most complex wartime rail movement plan in history.⁴

Hajo Holborn observed that, "The superiority of the Prussian Army in the 1860's was made possible only by its organization, by its peacetime training, and by the theoretical study of war."⁵ Many elements of the Prussian Army played a role in this development; however, the GGS played the key role, especially in the "theoretical study of war." In this study it will not be possible to undertake a full study of the GGS. Still, it is necessary to outline the situation faced by the GGS when Moltke became chief. In addition it is important to examine briefly the staff process used by the GGS.

Strategic Situation

Prussia's strategic situation between 1857 and the First World War was at best precarious. Lying in the middle of Europe, it was surrounded by potential enemies. In 1857, the most serious threats came from France, Russia, and Austria-Hungary. By 1914 the most likely antagonists were France, Russia, and Great Britain; however, the basic strategic situation had not altered.

It is well to remember that being surrounded by potential enemies is a more serious problem in Central Europe than in many other parts of the world. This is due to the relatively small size of Central Europe. Even pre-1914 Germany was a small country, covering only about 507,000 square kilometers.⁶ The distance from the Russian border to Berlin was less than 400 km, while the distance from the French border to Berlin was approximately 650 km.⁷ At its widest point, Germany was

not more than 1,200 km from end to end,⁸ about the distance from Washington D.C. to St. Louis.⁹ For the GGS, the proximity of potential enemies was a source of serious concern. The problem was also compounded by the fact that, except for some rivers, Germany had no natural features to protect its borders.

Dennis Showalter has pointed out that in 1836 the general staff calculated that a corps consisting of 24 battalions, 28 squadrons, and 96 guns could march a distance of 85 km in 16 days.¹⁰ At this slow rate it would take 75 days to cover a distance of 400 km. As slow as this may seem, it must be remembered that a defending army would travel at a similar rate. By 1914 armies were covering this distance in less than half that time.¹¹ This improvement was primarily due to expanded use of railroads, and the improvement of the road network throughout Central Europe.

These figures are only examples; however, they serve to point to the heart of the Prussian's problem from 1857 until World War I. Not only were Prussia's enemies near, there was the real potential of having to simultaneously fight more than one opponent at the same time. The likelihood of having to fight a two-front war would dominate war planning until the First World War. The chief question for war planner being in the event of such a war, was who to concentrate against first. This dilemma, more than anything else, would influence Prussian ideas about strategic mobility.

Not only were Prussia's enemies near, they were also large. In 1857 the total population of all the German states was slightly over 34 million. By 1914 the population of Germany was almost 65 million.¹²

Below is a comparison of the male population of Prussia and Germany with that of its three largest potential adversaries:

	<u>1857</u>	<u>1914</u>
France	18 million	19 million
Russia	60 million	70 million
United Kingdom	<u>10 million</u>	<u>17 million</u>
Total	88 million	106 million ¹³
Prussia/Germany	16 million	32 million

With these populations, Prussia's potential enemies had a population advantage of 5.5:1 in 1857, and one of 3.3:1 in 1914.

This makes the situation appear simpler than it was. Prussia's foreign relations between 1857 and 1914 were complicated. Its relationship with each of the above-mentioned countries varied throughout the period. At various times during this period any of the nations listed were just as likely to be aligned against each other as against Prussia.

Although Prussia, and later Germany, was a major power in Central Europe, it was not, despite its military performances in 1864, 1866, and 1870, more powerful than the collective strengths of its possible opponents. This became especially critical after the turn of the century when German foreign policy and a series of international events isolated Germany from most of its European neighbors, Austria excepted. This increased the likelihood that it could face a two-front war.

War Planning

War planning in Prussia, like in most bureaucratic countries, was not a simple process. Not only is the process by its very nature complicated, but Prussia's military decision-making structure was compartmented. Arden Bucholz observed:

The Great General Staff had charge of war planning and operations, including mobilization, training, and foreign intelligence. The office of the War Minister had responsibility for the technical backup of the army, including the nature and quantity of armaments. The military cabinet, the personal aide-de-camp of the Kaiser, concentrated on higher personnel decisions. After 1889 creation of a fourth body, the Kaiser's military headquarter, further complicated the situation.¹⁴

All of these agencies had access to the Kaiser under certain circumstances. In general the various agencies functioned well together, although a certain amount of bureaucratic rivalry was certain to occur. Since the general staff was primarily responsible for mobilization, and hence railroads, this is where we will concentrate.

The general staff had two broad goals during the period. One of these was to maintain an appropriately sized and trained army. The second was to develop sufficient plans to be able to employ this army to protect national interests. By the late 1880s, these broad goals had taken the form of demands for a larger army, and war plans capable of defeating one or more enemies, probably at the same time.

It is important to understand that by 1870 at the latest, the general staff was struggling with two related, but vastly different types of problems. One was the problem of fighting two or more opponents of superior size in a two-front war, while at the same time employing a rapidly growing army of her own. It almost goes without

saying that fighting a two-front war over a distance of 1,200 km is a strategic challenge. What may not be so easily seen is that training, equipping, moving, and employing a rapidly increasing army is also challenging. As Bucholz notes,

To put an army of such size into the field took very detailed plans, worked out in advance, and practiced, insofar as possible, during peacetime maneuvers. It required complex railroad and road timetables, long-range supply and logistical plans, and above all a minimum block of time, perhaps thirty days.¹⁵

By the 1870s the Prussians had a fairly advanced war planning process based on detailed plans tested and verified through the war gaming process. Plans found to be acceptable were adopted. Gunther Rothenberg describes this process by saying, "Each year the Great General Staff developed different contingency plans which, if adopted after being tested in staff rides and war games, became effective on 1 April the following year."¹⁶

Moltke entrusted much of this work to Colonel Jacob Meckel,¹⁷ a Hanover War School instructor. Meckel's system was based on the use of several elements that added realism to war gaming. These included the use of scaled maps, regulated movement times for units, an exercise time to real time ratio, transmission of orders throughout the exercise, and a casualty formula for different types of engagements.¹⁸ By 1870s standards this was a fairly advanced war gaming model and clearly displayed many of the characteristics of modern war gaming. In the mid-1870s Captain Naumann would develop a more complete casualty formula based on the experiences of the Franco-Prussian War.¹⁹ In addition to mathematical casualty tables, Naumann developed factoring formulas based on such factors as exhaustion, confusion, surprise, and fright. He also

based his formula on whether the attacks were frontal assaults, flank attacks, or pursuits. While somewhat subjective by its very nature, it did add increased elements of realism to war gaming.

In addition to war games, the GGS made extensive use of staff rides and large-scale maneuvers. Staff rides usually involved 30 to 50 officers taken from the GGS, subordinate staffs, or active duty units. The GGS held these staff rides outdoors and used them as miniature "strategic war games,"²⁰ with participants dividing into opposing sides. Each side competed against the other, using the Prussian war gaming model. The GGS usually held these staff rides in border regions, and they were at least loosely related to current war plans.

The Prussian Army conducted its maneuvers in a sequenced series beginning in late May or early June, and culminated in the Kaisermanoever, a large-scale affair planned, judged, and criticized by the general staff in early September.²¹ Even in these planned exercises the standards of command and performance were high. The army required units to keep detailed records of their actions. After various phases of the maneuvers, general staff members conducted the nineteenth century's version of an After Action Review (AAR).²²

Major departments of the general staff also conducted war gaming exercises of their own, especially during the winter months. All staff officers participated in various aspects of these winter war exercises. Two of the most important of these were the Railroad Section (RRS) and the Telegraph Section. The departments conducted communication, deployment, and mobilization exercises in conjunction with, and independent of other major exercises. These exercises had not only

training purposes, but were also designed to develop solutions to problems perceived by the GGS or the particular departments. Just prior to the First World War, both of these departments had begun to use electrical communications to conduct exercises without ever physically moving any soldiers or equipment.

War gaming was important to Prussian war planning. This was especially true in the period 1871-1914, when the Prussian Army saw almost no military action other than training. War gaming enabled the Prussians, at least to some degree, to validate their war plans.

Increasingly, war games changed operational planning. This was especially true as Prussia grappled with its two most pressing problems: how to fight a two-front war, and how to train, mobilize, and employ a larger army. War gaming made the Prussian general staff increasingly aware that employing a large army over vast distances, in a two-front war, against enemies armed with modern weapons of war is a complicated endeavor, beset with potential problems. The story of the general staff between approximately 1870 and 1914 is essentially one of a struggle to overcome these "potential problems".

Strategy

At this time it is important to say something about the Prussian concept of strategy. Under Moltke's influence strategy meant something different than it would later under Schlieffen's leadership. Moltke once described strategy as follows:

Strategy is a system of ad hoc expedients; it is more than knowledge, it is the application of knowledge to practical life, the development of an original idea in accordance with continually

changing circumstances. It is the art of action under the pressure of the most difficult conditions.²³

Under Moltke, an operational plan, for all its complexity, was basically an *Aufmarschplan*, that is a general deployment plan. It was not a detailed campaign plan. This was in part due to the Prussian Army's tradition of *Auftragstaktik*, or mission orders.²⁴ More importantly, it was due to Moltke's view of what strategy or a strategic system could or could not accomplish. Daniel Hughes once described Moltke's mindset by saying, "First and foremost, like Clausewitz, Moltke had no faith in systems of any kind. His system consisted of a pattern of thought rather than a series of procedures to be followed or successive tactical acts to be performed under all circumstances."²⁵

Moltke believed that the role of the general staff in operational planning was to deliver a mobilized army to the critical point on the battlefield and supply it once it was there. Other than providing broad guidance, there was not much the general staff could do. The remainder of the war was the responsibility of the field commanders.²⁶

Under Schlieffen, the GGS's role in strategic planning changed. The wartime plans prepared by the GGS after 1905 showed themselves to be for all practical purposes campaign plans, as opposed to mobilization plans. Arden Bucholz writes,

The plan of December 1905-January 1906 differs in one other significant respect from previous Prussian-German plans. It was not just an *Aufmarschplan*, that is, a deployment plan for the first few days of fighting; it was a technical-mechanical plan for an entire campaign to the end of the war, an advance through Belgium and across France planned like a field drill exercise, down to the concluding gunshot.²⁷

This change in thinking about the nature of operational plans affected all aspects of planning, in particular the more technical aspects of planning. This was to have a profound influence on the way the military looked at the use of railroads. This will be examined more thoroughly in subsequent chapters.

Railroads

Moltke recognized that putting a large army into the field, even against a single enemy on one front, was a complicated affair. The wars of 1864, 1866, and 1870 had provided ample evidence of this. The continuing increase in the size of armies did not seem likely to simplify this problem. In addition Prussia's lack of any significant natural frontiers made the matter even more acute. Prussia had to mobilize a large army rapidly, and deploy it (most likely) against two or more opponents on two fronts. Under these circumstances, timing and precision of execution become critical. As Dennis Showalter states, "Lacking natural frontiers-timing was all important for Prussia."²⁸ Walter Goerlitz observed, "The fundamental problem was simple; it was a question of beating one opponent by concentrating against him the greatest possible superiority of force and then falling as rapidly and as violently as possible on the other."²⁹ The Prussians struggled with this problem from the time of Moltke to the time of Moltke the Younger.

Moltke had become convinced early on that the key to victory lay in the ability to mobilize quickly and defeat an opponent before the opponent could mobilize. As Daniel Hughes has pointed out, "His famous statement that a mistake in the original deployment could hardly be made

good in the entire course of a campaign reflected his concern over flexible deployment linked to the subsequent campaign."³⁰ Moltke, in conjunction with Aristotle, believed that a little mistake in the beginning means a fatal one at the end.

Moltke, and those who came after him, recognized that railroads offered Prussia two great opportunities: an orderly deployment and the ability to overcome the factors of space and time. Arden Bucholz observed, "Railroads promised the essentials of speed, volume, and regularity and dependability by which a smaller army could defeat two larger ones on opposite geographic frontiers."³¹

In railroads Moltke saw a method of overcoming Prussia's strategic disadvantages. This was especially true in the area of separation versus concentration. One of the great difficulties facing large armies was how to keep sufficiently separated on the march to be able to get to the battlefield, and yet concentrate enough once on the battlefield to achieve mass for battle. To illustrate the problem in 1914 the railcars needed just to move one army corps would stretch for twelve miles behind the corps.³² This of course supposes that the entire corps was moving at the same time, which was not normally the case, but it does illustrate the problem. In 1914 Germany had 25 active duty corps.³³ This number of units would tie up 300 miles or 480 kilometers of track, assuming that there was sufficient rolling stock to move the entire army at once, which there was not. Still, since most, if not all of the track used in an initial deployment would be in a forward operating area, the problem of congestion is still a real one.

The only way to avoid a complete disaster was the precise execution of movement plans worked out long before.

The Prussians thought the railroad would allow them to overcome certain real or perceived strategic shortfalls. Railroads, while extremely important, were only one piece of Prussia's wartime movement plan. In fact, under Moltke's direction the military also began to develop plans to make use of Europe's rapidly expanding road network.³⁴ Still, railroads would occupy a central position in Prussian war planning unequal to any other system. Hajo Holborn reminds the reader that, "In fact, the timetable of mobilization and assemblage together with the first marching orders, formed in the future the very core of the strategic plans drawn up by the military staffs in expectation of war."³⁵ The remainder of this study will explore the consequences of railroads being the "very core" of strategic planning. While doing this, it is important to keep in mind Moltke's dictum that, "Great successes in war are not achieved, however, without great risk."³⁶

Early Years

Prussia manufactured its first railroad engine in 1815.³⁷ It was built by a group of businessmen as part of a joint business venture. Railroads expanded rapidly in Prussia from six kilometers of open track in 1836, to 240 kilometer in 1838, and 469 kilometer in 1840.³⁸ By 1860 Prussia had 11,089 kilometers of open track, more than any other nation in Europe.³⁹

In 1839 Prussia conducted its first major troop movement, 8,000 troops from Potsdam to Berlin along privately owned railroads.⁴⁰ In

September 1858 Prussia conducted its first large-scale peacetime railroad exercise. Over 16,000 troops, 650 horses, and 78 supply wagons were transported to maneuver areas and later returned to their garrisons.⁴¹ In 1859 Moltke created the Railroad Section (RRS) in the general staff.⁴² Thus a trend had begun which more closely tied the strategy of Prussia with the capabilities of her primary means of mobility--railroads. At this same time on the other side of the Atlantic, two more armies were learning about railroads.

American Civil War

Between 1861 and 1865 the Americans fought the Civil War. How much influence the Civil War had on the Prussians, or any other European country, is open to debate and well beyond the scope of this study. What is certain is that both sides in the Civil War made extensive use of railroads. The Prussians sent observers to watch the Civil War and after the war the Prussians noted several of the American experiences with railroads. Writing about the influence of the Civil War on the Europeans Jay Luvaas says,

The Americans had been the first to wage war over great distances largely by means of the railroads, and the creation of a separate corps to operate trains and maintain equipment, the use of armored trains and the evolution of the hospital car can all be traced directly to the Civil War.⁴³

Railroads had been in use prior to 1861. Their military applications, however, had been sporadic. The British and French had put them to limited use in the Crimean War in 1854. The French had deployed troops to Italy in 1859 using railroads. The Prussians had noted all of this and had already begun the detailed study of railroads.

Still the Civil War could not be ignored. As Jay Luvaas notes, "The Prussians had started to study railroads many years before. Prior to 1861 nothing had been done other than ordinances for troop movement."⁴⁴ Luvaas adds,

The Civil War was commonly regarded in Prussia as a testing ground for the military application of railroads. With the exception of the military use of railroads, the Civil War does not appear to have had any direct influence upon official doctrine in Prussia.⁴⁵

Like several European states, the Prussians sent observers to the American Civil War. Probably the most important of these was a young captain named Scheibert. Scheibert wrote on a wide variety of topics, to include railroads. His observations about the American use of railroads were insightful and closely studied by the Prussians. His key observations were the following:

1. Railroads were primarily developed to overcome vast distances and the poor conditions of roads.
2. Rivers and railroads were of paramount importance to strategic mobility.
3. In turn, the railroad itself became a military goal.
4. Battles were to be fought for the possession of junctions, and those junctions, for strategical reasons, were of first importance.⁴⁶

None of these ideas were novel to the Prussians; however, it was interesting to see them confirmed as a result of battle experience. The Prussians also paid close attention to the observations of a group of British observers. A translation of these observations were published in 1866 and included the following insights:

1. When available, railways have a great advantage in a theater of war as an auxiliary means of moving troops, and as a principle means of supplying them.

2. Railroads are more easily destroyed, but more easily repaired than roads.
3. One line is sufficient to support a field army.
4. Strategic tracks should be double track.
5. Commanders should not rely on railways in enemy territory.
6. Railroads are best suited for defensive operations.⁴⁷

The Prussians may not have adopted, or for that matter even agreed with, all of the observations of Scheibert or the British observers. What is important is that the Prussians were aware of these observations, and these observations served to generate many discussions about the military application of railroads.

Some other lessons that came out of the Civil War which the Prussians took to heart were the need for special units to operate or coordinate rail operations; the problems of different size track gauge; the delays involved in multiple changes in cars, trains, tracks, etc.; and the need for railroad repair teams to mend damaged or unserviceable track.⁴⁸ This is demonstrated by the fact that by 1866 practically all track gauge throughout Germany was the same, and most wagons and locomotives were interchangeable. Also, in 1866 Prussia created the Field Railway Section (Feldeisenbahnabteilung) and railway repair battalions.⁴⁹ All of these represented major steps in effecting the military use of railroads.

Further Developments

Before moving on to look at the characteristics of railroads, one must ask what the Prussians of the late 1860s hoped to accomplish through the use of railroads. Hajo Holborn suggested that the military

aspect was the dominant consideration.⁵⁰ There is no denying that military considerations were foremost in Moltke's mind; however, other factors were also important. For example, the fact that railroads had civilian uses also helps explain their development. As Dennis Showalter writes, "Railroads offered a substantial improvement in military efficiency, which would profit the civilian community as well."⁵¹ This explains the development of railroads during the period 1857-1914. For not only was this an important period of military development, but it was also an important time for industrial and business expansion. The fact that business and industry could also use railroads played no small part in their development in Prussia, as elsewhere.

The relationship between the military and civilian use of railroads is important. Civilian money paid for much of the expansion of the Prussian/German railroads. It is also important to note that by 1907 the Railroad/Telegraph Service employed nearly one million men,⁵² or about one out of every eighteen men of working age.⁵³ Contrast this with the fact that the present German railroad system that employed slightly over 200,000 workers in 1992, and this in a reunified Germany. This represents less than one out of 500 working males.⁵⁴

Railroads and War

Moltke once remarked that Prussian strategy had to capitalize on four things: improved roads, railroads, military telegraph, and a corporate staff (i.e., the Great General Staff).⁵⁵ Leaving aside the value of the other three, what is it about railroads that made them so valuable to the Prussian military? What is it about railroads that

makes them valuable to any military? In this next section this study will briefly explore some general characteristics of railroads, along with their requirements, advantages, and disadvantages.

In a recent study prepared by F. D. Foxton for the Royal Military College of Science, Moltke is quoted as saying, "Build no more fortresses, build railways."⁵⁶ The same study has a chapter that opens by saying, "Perhaps the most efficient transportation method for armies at war is the train."⁵⁷ This is interesting considering it was published in 1993. The study cites several reasons to support this, the most important being the following:

- Rail travel provides a particularly stable carriage for the transport of casualties.
- Trains are excellent transporters of heavy bulk supplies (e.g., ammunition) because it is difficult to weight out railroad cars.
- It is possible for a small crew to transport hundreds of tons of supplies, thus freeing manpower for other functions.
- Rail cars can serve as temporary storage platforms for parked equipment and supplies awaiting delivery to the combat zone.⁵⁸

The author summarizes by saying, "Consequently, trains are very efficient in terms of logistic manpower and vehicle resources."⁵⁹ He illustrates this point by reminding the reader of some recent experiences from the Gulf War. Foxton writes,

The coalition forces in Saudi Arabia found themselves operating in a theater of operations which did not have the sophisticated rail network of Western Europe. They were expected to operate up to 700 km from their ports of disembarkation. As a result, massive road convoys had to take the place of trains. In the case of the British, who eventually deployed only one understrength division, this took all of the army's transportation corps to find men and vehicles to make up these massive convoys.⁶⁰

P. D. Foxton's point is illustrative. Railroads can be and most often are an efficient and economic means to move men and supplies about the battlefield, allowing armies to overcome the problems of space and time. John Lynn captures this idea well when he writes, "The major European land powers, most notably Prussia, harnessed the railroad to haul men, equipment and supplies over distances and at speeds never before possible."⁶¹ Not only could trains do this, but they could do it using less space than any other method available at the time. Moltke simply said of trains, "They enormously increase mobility, one of the most important elements in war, and cause distances to disappear."⁶²

To understand the uses of railroads, it is important to understand that railroads are not just pieces of equipment, they are a system of technology, consisting of much more than just locomotives and wagon cars. A failure to do this will result in a failure to understand railroads.

Arden Bucholz has argued that three factors control rail planning: size, space, and time.⁶³ To manage these requires order, discipline, and precision. To this list one should add advanced planning. This advanced planning takes many forms, to include planning and building of new lines, programmed improvements in existing lines, manufacturing of locomotives and rail cars, the development of timetables, day-to-day provisioning of existing operations, just to name a few. These are necessary whether or not a military plan using railroads is developed and inserted into an existing railroad operation.

For example, the problem of timing is interesting. This is a critical area because several trains, separated by distinct periods of

time, must use the same tracks. It requires detailed planning and precise execution to prevent chaos and allow for smooth operations. Bucholz has observed that synchronizing train schedules is a complex process and that timetables must be worked out years in advance. Even minor changes in time schedules can disrupt major portions of the rail system.⁶⁴

It is enough to recognize that by nineteenth century standard railroads were fairly advanced technological systems. As systems, the railroads had requirements, extensive ones at that, just to keep them going. At the same time railroads, while providing great benefits to their users, also placed requirements on the user. These requirements must be understood and placed in the proper context. In the next chapters this idea will be explored more fully.

Before moving on, it is important to take a moment to review what were some real advantages and disadvantages to the use of railroads. This will help to set a framework for evaluating the problem in later chapters.

Bucholz probably provided the best summary of the advantages Prussia saw in railroads by the following:

Moltke saw that the size of forces was becoming unique in war history and that only railroads would henceforth allow their full deployment. Railroads were of little use in moving forces into combat, but of great use in mobilization, concentration, and supply. Railroads could strengthen the defense, but they also permitted a new kind of offense based upon moving separated forces outside the battle area, then concentrating them on the battlefield.⁶⁵

In summary, the Prussians saw railroads as giving them advantages in four areas: mobilization, concentration, supply, and offensive operations. Railroads also permitted the Prussians to do

these things with much larger armies. The GGS believed railroads would improve their relative advantage against their likely opponents. Railroads were a technological system that gave the Prussians an advantage and one that the Prussians could operate and support with existing resources.

While the Prussians used and endorsed railroads, early on they recognized that railroads have certain shortcomings. Railroads require rail, and where rail does not exist, trains cannot go. Also, railroads cannot support advancing armies, unless these armies move along existing tracks. From the wars of 1864, 1866, and 1870 the Prussians had learned about some of the problems of the railhead, and about the difficulty of transferring troops and supplies forward to the field armies.

The Prussians also recognized that adapting a railroad network to military use presented certain problems. Railroads are a system with certain characteristics. These may be modified to meet specific needs, but the system still retains certain influences. Because railroads are systems, they are, by necessity, dominated by technocratic management rather than "traditional" military command authority. Dennis Showalter reminds us, "But the influence of railroads on military doctrine depended on track mileage and layout, on careful organization and precise administration, at least as much as on the speculation of senior staff officers."⁶⁶ Later chapters will again examine these "technical" factors and their implications.

Not only do the laws of physics impose operating rules upon railroad systems, they also impose rules upon armies who use railroads.

Before looking more closely at railroads, it is necessary to outline the Prussian logistics system and how it functioned.

Prussian Logistics System

The basic structure of the Prussian, and later German, logistics system changed little in the period 1857-1914. The Prussians developed their logistics system around a system of army depots that supported storage areas, which in turn supported armies in the field. The forward storage areas were normally under the control of the field armies. The Prussians called this system *Etappen*,⁶⁷ which means a system of connected stages or echelons. This system had five main components: factories or sources, army depots, forward storage areas, field armies, and using units.

Factories and other sources produced the products needed by the army. Sources other than factories might include farms, horse stables, rock quarries, and timber merchants. When possible, the army placed centralized orders with factories and large firms. With fresh food and fodder this was not always possible, in which case field units made local purchases. In general, army units tended to rely more on local purchases during peacetime than during combat operations.

The army shipped goods purchased from factories to army depots, normally by rail. It did the same with purchases made from large firms or farms. In addition to army or war ministry level purchase, many depots were authorized to make independent purchases. This was particularly true for items like food or forage.

Depots varied greatly in size. Depots that stored ammunition and equipment were mostly long term storage locations, while those holding food and fodder usually turned over their stocks rapidly.

Army depots shipped their supplies to forward storage areas that were normally operated by the field armies, although in some cases these were operated by army headquarters. Most depots were connected by rail to the forward storage areas. Roads connected some smaller depots to forward storage areas. In such cases supplies and equipment were moved by horses and wagons. Most forward storage areas were located at or near railheads. Normally, rail connections did not extend beyond the forward storage area.

Forward storage areas received and configured supplies for shipment to the corps and divisions. Supply companies belonging to corps or divisions picked up and moved these supplies to the corps or divisional areas where they could be picked up by the subordinate units. Horses and wagons moved almost all supplies forward of the railhead. As will be demonstrated, this often proved a cumbersome process.

Horses were critical to the Prussian supply system and all Prussian/German field units. For example, in 1870 the Prussian Army fielded 260,000 men and 84,000 horses.⁶⁸ This is a ratio of 3.1:1. In World War I the German Army used fourteen million horses.⁶⁹ In addition to moving supplies, horses and wagons transported wounded soldiers to field aid stations and then to field hospitals. Despite this importance, the army allocated only a relatively small number of wagons to logistics functions. In 1914 a corps headquarters had 60

wagons dedicated to supply operations. A division had half that many.⁷⁰ Troop units might have one or two supply wagons.

The volume of supplies consumed by armies prior to 1914, although much lower than today, was still not insignificant. In 1870, an army corps would consume approximately 108 tons of supplies per day, with most of this being food and fodder.⁷¹ Ammunition consumption rates were still low enough that armies routinely deployed with all the ammunition required for an entire campaign. By 1914 this was no longer true. Corps consumption rates in 1914 were five times what they had been in 1870.⁷²

Forward storage areas were not expected to store supplies for long periods. In theory they were transfer points, keeping stocks no more than one to two days. As the railroads delivered supplies, corps and divisional supply companies were expected to pick them up promptly. During wartime operations this was often not the case. The horse drawn supply columns were less efficient at moving supplies forward than the railroads were at delivering them. During the war of 1870 numerous examples of this problem abound. Martin Van Creveld cites one example in June 1870, when one Prussian Army had 17,920 tons of supplies trapped at its railheads. This represented approximately 28 days of supplies and 14 times the storage areas intended capacity.⁷³

Larry Addington cites another example from the Prussian Second Army. He notes that on 5 September 1870 it had 2,300 loaded railcars with 16,830 tons of supplies waiting to be offloaded at its railhead.⁷⁴ Addington believed this resulted from the shortage of horses and wagons

and their low load capacity and low marching speed in comparison to trains.⁷⁵

Heavy supply companies picked up the supplies and moved them into corps or divisional areas where battalion supply wagons could pick them up. Battalion supply wagons were usually smaller than those of the heavy supply companies, and pulled by fewer horses. Ideally, these supply wagons would deliver supplies to the forward companies. In many instances soldiers moved supplies to their final distance by hand. Prior to 1914, most of the supplies moved forward were food and fodder. After 1914 ammunition represented a much higher volume of supply, but still it was fodder which represented the highest volume and tonnage of supply.⁷⁶

Evacuations worked in reverse order to the distribution of supplies. The most common types of evacuations were wounded soldiers, wounded horses, and damaged equipment. The Prussian Army had special wagons to move wounded soldiers and horses, but when these were overtaxed any available transport wagons were used. Casualties and damaged equipment were usually moved by horse and wagon until they reached a railhead. There they boarded trains and moved by rail.

In addition to understanding the transportation arrangements of the Prussian army it is necessary to look briefly at procurement. Procurement procedures in the Prussian army were complicated, and often added to the burdens of the transportation system.

The Prussians used three types of procurement. These were (1) centrally managed, centrally distributed items (e.g., ammunition), (2) items centrally managed and distributed but for which subordinate units

were authorized to purchase directly on an as needed basis (e.g., horses), and (3) items which units were expected to purchase locally in order to supplement issues received from army sources (e.g., food and forage). Each type of procurement had its benefits and pitfalls.⁷⁷

The primary challenge with centrally managed, centrally distributed items was distribution. Field armies distributed supplies received from the army depots. Although somewhat unresponsive at times, this system was the easiest for planners at the corps and divisional level. In short, armies sources provided supplies, or they were not received at all. Units were not expected to make up unpredicted shortfalls. This was not the case with the other two types of procurement.

Horses were a different story. The war ministry, on a yearly basis, attempted to determine the number of horses needed by the military and the number of horses available for purchase. This was not an exact process. Requirements varied from year to year. Additionally the available horse population varied from year to year, and by 1900 most of Germany's horse population was concentrated in East Prussia, while most of the army was garrisoned west of the Rhine. These factors complicated the purchasing horses for the army.⁷⁸

Despite the war ministry's best efforts there were always local, and often general, shortages of horses. The army authorized units to make local purchases to correct this problem. Units in East Prussia could normally make up their shortfalls through local purchases. Units stationed in the West could not. In such cases the war ministry or field army headquarters would attempt to buy additional horses to fill

any shortfalls. While waiting for additional horses, units frequently experienced serious transportation shortfalls. Since shortages of horses were somewhat unpredictable, units had difficulty planning for these horse shortages. When horse shortfalls became widespread, which after 1900 was increasingly common, the ability of significant portions of the army to transport their supplies beyond the railhead was seriously impaired.⁷⁹

The situation with food and forage was even more complex. All field units supplemented their army issues with local purchases. During peacetime this arrangement worked well enough. In wartime the problems were much greater. There was the problem of transporting the food once found, not to mention the difficulty of finding it in the first place. As previously noted, corps units and below were hard pressed to distribute the supplies they received from the army depots. When scarce wagons and horses had to be sent to pick up local purchases of food and fodder, the transportation situation worsened. The fact that units had difficulty predicting how much food and fodder they needed to purchase locally further complicated the problem.⁸⁰

As is evident, the strategic distribution of supplies in Prussia, and later Germany, was fairly advanced by the standards of the late nineteenth and early twentieth centuries. Forward of the railhead, however, the situation was different. As Van Creveld observed, "The armies of 1914 were still dependent on those time-honoured means of locomotion, the legs of man and beast."⁸¹ Subsequent chapters will examine what were the outcomes when the railroad came face-to-face with this type of logistics system.

CHAPTER 2

LITERATURE REVIEW

The Prussian Army between 1857-1914 has been extensively covered both in general and specialized works. Unfortunately, the use of railroads, and their subsequent logistical implications, have not been as well covered in the more readily available sources. The Prussian use of railroads is mentioned in a wide variety of works; however, these comments tend to be general, and usually only address strategic mobility. A comprehensive work on Prussian logistics for the period in question has not been published.

The best English language starting points for a study of railroads and their role in Prussian war planning are Arden Bucholz's Moltke, Schlieffen, and Prussian War Planning and Dennis Showalter's Railroads and Rifles: Soldiers, Technology and the Unification of Germany. Both of these works describe the development of military railroads in Prussia and explain the role of railroads in Prussian war planning. They also discuss some of the key logistical and technological problems associated with the use of railroads.

Both books are comprehensive studies of Prussian war planning; however, they primarily emphasize Prussian's western areas of operations. To balance this, Graydon Tunstall's Planning for War Against Russia and Serbia: Austro-Hungarian and German Military

Strategies, 1871-1914 is recommended. Dennis Showalter's Tannenberg, Clash of Empires is also a good introduction to the dilemma of planning a two-front war. Neither work discusses logistics in great detail, but both address the planned use of railroads for strategic mobility.

This study found no comprehensive study of Prussian logistics from 1857-1914. Fortunately, other studies devote some discussion to the role of railroads in Prussian strategic mobility and logistical planning. Martin Van Creveld's Supplying War: Logistics from Wallenstein to Patton has one whole chapter on the Prussian use of railroads. As a balance to Van Creveld Feeding Mars: Logistics in Western Warfare from the Middle Ages to the Present, edited by John A. Lynn is suggested. Its essays address a wide variety of topics. Lynn prepared this work in light of recent research on many topics originally brought to the forefront by Van Creveld.

Other important works to consult include Julian Thompson's The Lifeblood of War: Logistics in Armed Conflicts, Kenneth Macksey's For Want of a Nail: The Impact of Logistics and Communications, Martin Van Creveld's Technology and War, and Kuhl and Bergmann's Movements and Supply of the German First Army During August and September, 1914. All of these works discuss the impact of railroads on military operations and help put the Prussian experience into perspective. There are several essays that discuss the impact of modern technology on warfare. An outstanding introduction is Michael Handel's "Clausewitz in the Age of Technology" in Clausewitz and Modern Strategy edited by Michael Handel. This essay describes technological changes in light of the effects they have had on theories of warfare. Another important essay

is Michael Howard's "Tools of War: Concepts and Technology" in Tools of War: Instruments, Ideas, and Institutions of Warfare, 1445-1871, edited by John A. Lynn. Dennis Showalter's "Weapons and Ideas in the Prussian Army from Frederick the Great to Moltke the Elder," also in Lynn's book, is a good introduction to how inventions and technology influenced Prussian, and later German, military planning and operations. It is recommended in conjunction with Showalter's other works.

Bradley Smith has written three monographs on the military use of railroads. These are entitled "The Influence of Railroads Upon Campaign Plans," "The Role of Army Railroading at the Operational Level of War," and "The Role of Army Railroading at the Tactical Level of War." He wrote all of these while a student at the School of Advanced Military Studies (SAMS), and all of these were published as SAMS Monographs. Smith's emphasis is on the role of the railroad in the American military, however, many of his observations are universal.

P.D. Foxton's Powering War: Modern Land Forces Logistics is a recently published study by the British Staff College. While focusing primarily on NATO logistics in a European environment, it is an analytic study and a critical introduction for one who wishes to understand logistics in a European context.

There are many works available on the Prussian Great General Staff during this period. Among the best still available are Walter Goerlitz's History of the German General Staff 1657-1945, Gordon Craig's The Politics of the Prussian Army 1640-1945, and Larry Addington's The Blitzkrieg Era and the German General Staff, 1865-1945.

These are standard works, and I highly recommend all of these. Also available and worth reviewing are Christian Millotat's Understanding the Prussian-German General Staff published by the U.S. Army War College, and T. N. Dupuy's A Genius for War: The German Army and General Staff, 1807-1945.

Helmuth von Moltke wrote extensively and several of his works are available in English (translations). Probably the most comprehensive among these are On the Art of War: Selected Writings, edited by Daniel J. Hughes. Also available are The Franco-German War of 1870-71, and Strategy: Its Theory and Application: The Wars of German Unification 1866-71, edited by Thomas E. Griefs and Jay Luvaas. Moltke wrote in a clear and insightful manner, and his writings shed a great deal of light on his understanding of problems facing the Prussian military.

There are numerous essays on the Prussian Great General Staff. Two good introductory essays are Hajo Holborn's "The Prusso-German School : Moltke and the Rise of the General Staff" and Gunther Rothenberg's "Moltke, Schlieffen, and the Doctrine of Strategic Development". Both of these are included in Makers of Modern Strategy, edited by Peter Paret. Michael Howard's "Men Against Fire: The Doctrine of the Offensive in 1914", included in the same volume is also a useful introduction, as is Dennis Showalter's "Total War for Limited Objectives: An Interpretation of German Grand Strategy" contained in Grand Strategies in War and Peace edited by Paul Kennedy.

The volumes covering German history, or a given aspect, are so numerous that I can only briefly describe a few. Hajo Holborn's A

History of Modern Germany, published in three volumes, is an excellent introduction to German history. Holborn devotes extensive sections to the period 1857-1914. Hans-Ulrich Wehler's The German Empire 1871-1918 is an outstanding survey of the latter part of the period by a German scholar of high reputation. Imperial Germany, edited by James Sheehan, is another solid introduction to this period. This book contains a series of essays by scholars including Hans Rosenberg, Otto Pflanze, and Wehler. All of these works help describe the background to the period.

The years 1866-1914 are another period widely covered in print. Michael Howard's The Franco-Prussian War is a good introduction to this period. A useful balance to Howard's work is Thomas Adriance's The Last Gaiter Button: A Study of Mobilization and Concentration of the French Army in the War of 1870, which despite its title also discusses the situation faced by the Prussians. Both books should be viewed against Moltke's accounts. Gordon Craig's two works, The Battle of Koeniggraetz, and Germany 1866-1945 are both invaluable sources for this period. Some important essays covering this period are Bruce Gudmundsson's "Maneuver Warfare: The German Tradition" and Franz Uhle-Wettler's "Auftragstatik: Mission Orders and the German Experience" both contained in Maneuver Warfare: An Anthology edited by Richard D. Hooker. Also useful is Williamson Murray's "Clausewitz: Some Thoughts on What the Germans Got Right" in Handel's Clausewitz and Modern Strategy.

Important works covering slightly broader periods include The War Plans of the Great Powers, 1880-1914, edited by Paul Kennedy, and Kennedy's own The Rise of the Anglo-German Antagonism, 1860-1914. The

First World War period is well covered in Fritz Fischer's two monumental works Germany's Aims in the First World War and War of Illusion: German Politics from 1911 to 1914.

The period just prior to and during World War I is well covered in Lancelot Farrar's The Short War Illusion: German Policy, Strategy, and Domestic Affairs August - December 1914, Robert Asprey's The German High Command at War: Hindenburg and Ludendorff Conduct World War I, and Michael Geyer's "German Strategy in the Age of Machine Warfare, 1914-1945" in Makers of Modern Strategy.

A good introduction to the development of heavy industry in Germany is William Manchester's The Arms of Krupp 1597-1968. A helpful survey of the German coal industry is provided in the introduction of John Gillingham's Industry and Politics in the Third Reich: Ruhr Coal, Hitler, and Europe.

Most of the works listed here provide detailed bibliographies which are a good source for further study. These will be helpful for anyone researching these topics.

CHAPTER 3

RESEARCH METHOD

Research Question

The primary question I intend to answer is "What were the logistical implications of Prussia's decision to adopt railroads as its primary means of strategic mobility? I will examine these logistical implications and how they affected the war planning process, and the actual conduct of operations. Some secondary questions I will address are (1) Given Prussia's geography and strategic situation, did it have any better options than to adopt railroads as its primary means of strategic mobility? (2) What logistical advantages did the Prussians perceive that they would gain from the effective use of railroads? (3) How did railroads fit into the Prussian logistics system? and (4) What were some underlying implications that accompany a decision to use railroads and how did these influence Prussian planning and execution?

I used a three-step approach to research. The first step was a collection and review of appropriate source and reference material. The second step was a critical evaluation of the information collected. The third step was the consolidation of information and preparation of this study. Using this method, I set out to answer my primary and secondary research questions.

My main sources of information were books, maps, documents, and articles from various sources. I concentrated on three main areas: the

war planning process, the development of the military use of railroads, and the influence on logistics of the use of railroads. I examined these against the backdrop of the Prussian military logistics system.

I first examined the Prussian war planning process, concentrating on the period between 1857-1914. I studied the general situation, special problems, and steps taken to prepare for war. Since the most pressing concern during this period was the potential of a two-front war, strategic mobility was especially important to Prussian war planners. The need to mobilize and move troops rapidly to different fronts was critical to all planning. By the later part of this period, strategic mobility had become in many instances, the single most important consideration for war planners.

I next looked at the development of the military uses of railroads and its consequences. I examined the Prussian uses of railroads, especially in view of the strategic challenges they faced. The Prussian Army was not the only military using railroads at this time, however, their war plans were more closely linked to rail movement than that of their neighbors.

Lastly, I looked at the implications, mostly logistical, which the decision to use railroads had for the Prussians. I did this in view of the logistics system used by the Prussians throughout the period. The challenge in this instance is to distinguish those effects caused by the railroad, and those that were simply the result of the general operation of the logistics system. This is important because logistical impacts are frequently the result of many complex factors. Like many

other things in this world, they are compound by nature. This requires a researcher to be cautious in his determination of causes and effect. Cause and effect relationships are complex and a failure to understand this may lead to oversimplification, or even incorrect conclusions.

After gathering information, I evaluated the facts. I was initially concerned about the results of adopting a technological system (e.g. railroads) at a given point in time. For example, railroads are not stand alone systems. A functioning railroad system requires many supporting technologies. These will include, but are not limited to, such things as steel industries, the availability of coal or other fuels, a network of stations and railheads, timber industries, signaling system, etc. All of these plus countless other items must exist naturally, be manufactured, or imported in order for the system to function. The degree to which these supporting technologies function, both overall and in relation to one another, have a tremendous influence on how well the system as a whole functions. For example, an extensive rail system supported by an inadequate domestic fuel supply, will have difficulty sustaining operations in wartime unless: (a) extensive stockpiles are on hand, (b) imports can be guaranteed, or (c) a method to boost domestic production is developed. Developing an extensive rail network without an adequate domestic fuel supply already implies certain logistical considerations, even if they are never realized.

Besides examining some technological implications of railroads, I looked at the role of railroads in war planning, some actual military uses of railroads, and how railroads linked with the overall Prussian logistics system, especially the transportation aspects. The last

aspect proved more insightful than I first imagined. I will discuss this in more detail in the next chapter.

My final step was preparing this study. I believe the methods I used and the sources I examined were adequate to answer the research question. More research can be done on this topic, but I think my study has addressed the critical area of the effect of railroads on the Prussian logistics system.

Assumptions

In this study I have kept my assumptions to a minimum. Still, I have made two major assumptions. These are (1) the continuing military link between Prussia and Germany up to 1914, and (2) the general reliability of the sources used, cited, or referred to in my research.

I have assumed the German military of 1871-1914, at least at the general staff level, to be a continuation of the Prussian military system. The point may be open to debate, however, it is not an assumption I have made lightly. I agree that there are differences between Prussia prior to 1871, and Germany after 1871. Yet, the links, both institutional and structural between the Prussian military before 1871 and the German military after 1871 are significant. This link is strongest at the general staff, and at the army level commands.

There are several reasons for believing this assumption to be true. The Prussian imperial leadership remained in place after 1871. The geographic and strategic situation Germany faced after 1871 was very similar to that of Prussia before 1871. Much of the senior army

leadership, especially at the general staff level, remained Prussian after 1871. The German military adopted many, if not most, of the Prussian military institutions. This included the Great General Staff and all its departments. Not only did Germany imitate most of Prussia's military institutions, but also its yearly war planning and exercise cycle.

The other assumption I made is that of the general accuracy of the sources I have used. This is not to say that some sources are more accurate than others on certain points. Similarly, I accept that on certain points some sources may be incorrect, or at best uncertain. What I acknowledge is that none of the sources is deliberately untruthful. All authors set out to write because they wanted to make a particular point, however, this does not imply that they purposely set out to mislead. This did not mean that I always agreed with my sources' conclusions. Rather, I conclude that most presented generally accurate information.

Limitations and Delimitations

I have placed two limitations upon this study. These are (1) I have limited myself almost exclusively to English language sources, either in the primary language, or in translation, and (2) I have limited my search to published sources. I do not believe that either of these will prevent me from accomplishing my study.

My command of German is modest. I have therefore used mostly translated sources. I was able to balance these translations against the works of scholars fluent in German and English. Based on multiple

comparisons I am confident that the translated sources were accurate enough to allow meaningful study.

I limited my research to published sources. Again, I do not see this as a major hindrance. It seemed to me that personal interviews were impractical, and would probably shed little light on an era so distant from ours. While I recognize that there are significant unpublished sources available, I elected not to use them because I am satisfied that the published sources are adequate to cover the topic. I am confident that my limitations are proper, and will not seriously hinder my study.

By answering the primary and secondary research question using the process I have outlined, I am convinced that I have been able to develop the topic properly and provide insightful research. I have already set the background in the opening chapter. In the next two chapters I will analyze the facts and put forward my conclusion about the logistical implications of the use of railroads.

CHAPTER 4

ANALYSIS

Now that I have identified the questions to be answered, outlined the method to be used, and provided some background information, it is time to proceed with my analysis. Before I do so it is necessary to discuss what must be analyzed, and I must clarify some logistics issues. Once I have done this, then I will proceed with my final analysis.

There are certain complexities associated with determining the logistical implications of the use of railroads. Both railroads and logistics are systems. As in the case of the Prussians, railroads were a part of their logistics system. Still, there are many components of railroads that are unique. These would exist, and be required, even if the railroads were not part of the logistics system. Likewise, there are many aspects of logistics that have nothing to do with railroads in particular, or even transportation in general.

As simple as this may sound, it is an important distinction. Whenever two or more unique systems are merged, or for that matter operate in conjunction with one another, it is important to understand these implications. Systems that are merged, or operate in conjunction with other systems have a greater complexity than single systems operating alone. This complexity can be seen in many ways, one of the most important being the difficulty in determining cause and effect

relationships. Since cause and effect relationships are one of the keys to understanding impacts it is necessary that I discuss this.

When something happens or fails to happen, the two most frequently asked questions are how and why. In essence, this is a search for a cause and effect relationship. Many of us make routine cause and effect relationships every day without realizing the complexity of the process we use.

Cause and effect relationships are not as simple as they might appear. For instance, if a particular system fails to perform a task for which it was developed, we ask the question why. In such a situation we must first determine what did not happen, and then determine why. Determining what did not happen is usually fairly simple, but finding the underlying cause is often more difficult.

The potential number of causes for a particular result is almost limitless. In general, however, causes fall into three broad categories. These are (1) causes internal to the operation of the system, (2) causes external to the system (e.g., acts of God), and (3) causes that have contributing factors both internal and external to the system. This basic model is valid for most systems to include railroads and logistics.

When two or more systems are merged or otherwise interconnected by their operations, cause and effect determinations take on an added complexity not seen in single systems. There are two reasons for this. One is simply that the total number of possible causes and effects is increased. The second is that entirely new categories of cause and effect relationships are created. In a single system causes are

internal to the system, external to the system, or the result of a combination of the two. When two or more systems are in operation, in addition to these potential sources, there are causes that have contributory factors from each of the component systems, and there are causes which have their origins in the mechanisms or processes that link the two systems.

This study concentrates on railroads and the logistics system of which they were a part. As such, at a minimum, it deals with two major systems operating in conjunction with each other. This is important to keep in mind when attempting to determine why something did or did not happen. For this reason it is necessary to pay close attention to (1) the operation of railroads as a system, (2) the operation of the logistics system, and (3) the operation of the two systems in conjunction with each other. A failure to study the situation from these perspectives could well lead to results being attributed to the wrong cause.

In addition to understanding the inherent complexities associated with multiple systems, there are certain logistical facts that need to be clarified. There are three logistical points I intend to clarify. The first of these are about the nature of consumption rates in the Prussian Army and other armies during the time period of this study. The second is the nature and evolution of supply base support for armies. The third point concerns the background and nature of the Prussian transportation system, especially that below the strategic level. These points require some clarification because they need to be understood in their proper perspective before I begin my

final analysis. It is not my intent to make a detailed study of any of these, rather, I hope to put some facts into perspective.

Consumption Rates

Even a casual student of war understands that army consumption rates have risen steadily over the past 150 years. Most attribute this to increases in ammunition and petroleum consumption. While in a general sense this is true, the story is actually much more complex.

Determining consumption rates for armies, especially those of the past, is difficult. Part of the problem is the changing nature of supplies. Supplies today are more varied and packaged much differently than items from 100 years ago. This affects the weight and volume of supplies. Another problem is the amount and nature of supplies drawn from local sources versus supplies drawn from supply bases. This is particularly important since horse fodder was not only the item most often drawn from local sources, it also represented the single highest volume of supplies by weight. This fact is not always clearly understood. Major studies indicate that food and fodder were the main items of consumption for armies prior to the First World War, while ammunition and petroleum were the main items after 1914. By weight and volume, fodder represented almost all the supplies that armies used prior to 1914, and even a very substantial amount throughout the entire First World War. Let us consider some examples.

John Lynn estimates that an army of 90,000 campaigning for a three month period during the period 1672-1697 consumed approximately 2,225,000 pounds (1,112.5 tons) of supplies per day. He bases this on

an army of 90,000 with 40,000 horses.¹ Almost all this consumption is food and fodder. For this army Lynn estimates that a soldier would eat 2.5 pounds of food and a horse 50 pounds of green fodder per day. Based on this, horse fodder represents 2,000,000 pounds of supplies, nearly 90% of the army's daily consumption.²

Another example is provided by Larry Addington. He states that in 1870 the Prussian Army fielded approximately 260,000 men, 84,000 horses, and required 1,848,000 pounds (924 tons) of fodder per day.³ It is interesting that Michael Howard puts the size of the force at 309,000⁴, but I will stay with Addington's numbers. Since this rate of consumption for fodder is almost half that estimated by Lynn, in the previous example one is left to assume that Addington is talking about dry fodder, of which a horse normally eats approximately 20 pounds per day, as opposed to 50 pounds per day of green fodder.

In another chapter Addington states that on 5 September 1870 the Second Prussian Army had 16,830 tons of supplies backed up at its railhead and this represented 26 days of supplies.⁵ According to Michael Howard the Second Army had six corps with a total of 134,000 men and almost 44,000 horses.⁶ Based on this the daily consumption rate for the Army would be 647 tons per day, or approximately 108 tons per corps per day. Using the above totals the daily consumption rate for the Second Army would be approximately the following:

<u>Supply</u>	<u>Consumption Rate</u>	<u>Percentage</u>
Food	168 tons/day	26%
Fodder	432 tons/day	67%
Other	47 tons/day	7%
Total	647 tons/day	

The above totals are based on horses eating exclusively dry fodder. This is important, for while 44,000 horses can survive on approximately 432 tons of dry fodder per day, they would require 1,100 tons of green fodder per day. Such a change would radically affect the daily consumption rate for the army. For example, using dry fodder an army of this size requires 647 ton of supplies per day. If the horses had to eat green fodder, the army would consume 1,315 tons per day. Not only is this twice as much, but the increase is due only to the change in the type of fodder consumed. In such a case, fodder would represent 90% of the army's total consumption of supplies.

By 1870, thanks largely to the availability of rail transport, dry fodder could be brought forward to supplement the green fodder available locally. Horses on campaign could not, however, always be supplied with dry fodder, so for a given period of time a horse's diet was likely to be a mixture of the two. Since the consumption rate for the two types of fodder varied so much, a requirement to change from one to the other had a significant logistical impact on an army. This affected not only the general consumption rate of the army, but also its procurement and transportation operations.

It is important to understand that fodder represented 67 percent of the total consumption of the army when the horses ate dry fodder, and

almost 90 percent when the horses ate green fodder. Historically, fodder had always represented the highest percentage of consumption by weight and in fact it would continue to do so right up through the end of the First World War. This is true despite the fact that ammunition consumption rates rose steadily throughout the later part of the period covered by this study.

This is not meant to imply that ammunition did not present a significant supply challenge; it did. Rather, I want to correct the commonly held belief that food and fodder were the main supply problems prior to 1914, and ammunition was the main supply problem after 1914. The actual situation was much more complex. While ammunition consumption rates soared steadily, food and fodder rates remained constant. The total consumption of food and fodder decreased only in those instances where the actual number of soldiers or horses decreased.

Part of the misunderstanding stems from the fact that the cycle of consumption for food and fodder varies from that of ammunition. Food and fodder have fairly consistent consumption cycles; men and horses need to eat each day. Ammunition consumption on the other hand tends to be sporadic, with periods of intense consumption followed by periods of low consumption. During periods of intensive usage, ammunition consumption will be higher than that of any other supply. Over an extended period of time, however, ammunition will not represent as high a proportion of consumption as is commonly believed.

James Huston provides an example of this from the First World War. During the period 26 September-11 November 1918 the U. S. Army fired a total of 4,214,000⁷ rounds of artillery in the European theater.

Based on the average weight of an ammunition shell for this period (35 pounds), this translates into 73,745 tons of ammunition, or a daily consumption rate of 4,609 tons per day. This is slightly higher than the consumption rate of a modern heavy division engaged in heavy combat.⁸ During this same time period the U. S. Army was feeding 1,892,600 men and 163,087 horses⁹ daily. The chart below shows a comparison of the consumption rates for food, fodder, and ammunition for the period 26 September-11 November 1918:

<u>Item</u>	<u>Daily Consumption Rate</u>	<u>Daily Total</u>	<u>Total for Period</u>
Food	2.5 lb/day	2,366 tons	37,856 tons
Fodder (dry)	20.0 lb/day	1,630 tons	26,080 tons
Fodder (green)	50.0 lb/day	4,077 tons	65,232 tons
Ammunition (Arty)		4,609 tons	73,745 tons

Ammunition has the highest daily and total consumption. The period 26 September-11 November 1918 was a period of high ammunition consumption for the U. S. Army. Likewise, the U. S. Army had a relatively low horse to soldier ratio, about 1:11.6. Had the ratio of horses to soldiers been the same as the German or British Army, approximately 1:3, then the total number of horses would have been 630,866 as opposed to 163,087. With 630,866 horses, fodder consumption would have been the following:

<u>Item</u>	<u>Daily Consumption Rate</u>	<u>Daily Total</u>	<u>Total for Period</u>
Fodder (dry)	20.0 lb/day	6,308 tons	100,928 tons
Fodder (green)	50.0 lb/day	15,771 tons	252,336 tons

In these cases fodder consumption would represent between 137% and 342 percent of the consumption of artillery ammunition. It is true that artillery did not represent all the ammunition consumption, but it did account for about 80 percent of all ammunition consumption by weight.

The point is not that ammunition consumption was so low, it was not. It is that the nature of consumption throughout the period is more complex than just food and fodder, or just ammunition. Even as late as 1918, armies were just as likely to be concerned with procuring and transporting food, and especially horse fodder, as they were about ammunition. Summing up the experiences of the First World War, James Huston writes, "As was later pointed out, the greatest single class of supplies shipped by the British to France was hay and oats-5,439,000 tons, as compared to 759,000 tons of gasoline and oil."¹⁰

While the railroads dominated the strategic movement of supplies at the field army level and below, it was the horse that moved supplies and performed other key logistics functions. At the same time it was food for the horse that tied up more transport assets than any other commodity.

Supply Base Support

Another topic that requires some explanation is supply base support. Supply base support is supplying armies from stocks from the rear or home country versus the local procurement of supplies often referred to as "living off the land." In his book Supplying War Martin Van Creveld states, "By and large, the story of logistics is concerned with the gradual emancipation of armies from the need to depend on local supplies."¹¹ He goes on to argue that in general, armies during the period 1625-1914 lived off the countryside, while the coming of the First World War suddenly found armies bound by an "umbilical cord" of supplies from the rear.

Van Creveld believes this was determined by the nature of supply consumption for given periods of time¹². Ammunition consumption was modest until World War I and enough could normally be carried for an entire campaign. Only food and fodder were required in large quantities and these could be obtained locally. The mass consumption of the First World War changed all of this. The largest difference between World War I and the wars previous to it was the calibre and volume of ammunition consumed. Weapons, especially artillery pieces, were larger and could fire more rapidly than those used previously. In addition armies used more artillery, and for longer periods, than had been the case in earlier wars. This was partly a technological change, and partly a change caused by the stalemate on the Western Front. With armies locked into trench warfare, opponents poured vast amounts of artillery ammunition on each other in order to make marginal gains. Armies locked into trench warfare also used machine guns more than they

had been used before. This weapon has a much higher rate of fire than the infantryman's rifle, and contributed significantly to the increase in ammunition use at the company and battalion level.

To some, the above is a popularly accepted outline of the history of logistics. It is not entirely incorrect, however, the situation is more complex than suggested by Van Creveld. Supply arrangements in the period 1625-1914 were a mixture of supply base and local support. Whether or not an army depended more on supply bases or more on local supply depended upon a number of factors to include the type of campaign, the size of the army, the objectives of the campaign, and other factors.

Armies throughout the Thirty Years War relied heavily on pillage and plunder, while those of Louis XIV (1643-1715) relied primarily on supplies drawn from home station.¹³ The armies of Napoleon used both foraging and supply bases to support their campaigns. The Industrial Revolution made certain tools of war readily available that changed the nature and quantity of supply consumption. It also provided such things as railroads, improved roads, and better preservation techniques, which allowed more supplies to be moved from the rear.

When in the mid Nineteenth Century European armies, most notably the Prussians, began to make extensive use of railroads for troop movement and resupply from depots in the rear, these were innovative concepts, but not entirely new ones. Armies had, at least periodically, received supplies from rear supply bases for least at least 200 years previously. To say that supply prior to 1914 was "living off the land", and that after 1914 it transformed to an "umbilical cord" to the rear,

misses the complexity of the situation. In truth, armies during the period 1600-1918 relied upon both supply bases and local supply, depending upon the particular circumstances under which they operated. As we continue to analyze the effects of railroads on logistics it is important to remember that railroads represented another step in an already complex, evolving history.

Prussian Transportation System

I have mentioned the Prussian transportation arrangements. The system could best be summed up as consisting of railroads and a lot of horse drawn wagons. There were others, but without these two modes supplies and equipment in the Prussian Army did not move. Railroads provided most of the strategic and operational movement, while horses provided most of the tactical transport beyond the railhead. This mixture of two levels of widely diverging technology (i.e., modern and ancient) represented a less than ideal situation, however, two points must be noted. The first of these is that this arrangement was not unique to Prussia. The second is that this arrangement was one of necessity.

During this period most European armies relied on a mixture of rail and horse transport. This was true for the French, British, Russians, and Austrians, as well as the Prussians. The French and British did have more motor vehicles than the Prussians¹⁴, but even their armies relied heavily on rail and horse transport. The Prussians used an extensive amount of rail and horses, but their general transportation system was not unique.

The second point is that the railroad/horse system was one of necessity. It evolved because no other systems existed, or were available in sufficient quantities, that would better accomplish the mission. By the later part of this period, motor vehicles had begun to appear, but the domestic production level was not yet sufficient to support large military operations. Discussing the logistics of the Schlieffen plan, Holger H. Herwig writes, "It would have required 18,000 trucks to carry these combat forces-at a time when Germany possessed but 4,000 of which 60 percent broke down before they reached the Marne."¹⁵

The Prussians had to understand, if they stopped to think about it, that horses and wagons are not especially efficient at supplying modern armies. Between 1860 and 1914 the Prussians steadily employed larger armies that used more powerful, complex weapons. Consumption rates for ammunition and other explosives had steadily increased, while the consumption rates for food and fodder remained high. The development of the railroad enabled the Prussians to move large numbers of men and supplies from one strategic location to another. Yet, forward of the railhead the Prussian transportation system looked much like the one used by Julius Caesar 2000 years earlier. Why was this?

There are several explanations. The simplest answer is that nothing else yet existed to take its place. Technological changes are seldom uniform, even within one system. This was the situation with the Prussian military transportation system in the last decades of the 19th century. Railroads were at the cutting edge of 19th century technology, while horse transport was a throwback to another era. Describing this type of phenomenon, Van Creveld concluded,

As early as the last decade of the nineteenth century, another complaint about the effect of continuous technological innovation was being heard with increasing frequency: namely that the numerous changes in weapons and equipment would lead either to a badly trained army or to one that was well-trained but heterogeneous, and belonging to different technological ages.¹⁶

The Prussian military transportation system was clearly one whose various parts or subsystems belonged to different technological ages. Again, this was hardly unique to Prussia. This situation in Prussia was actually just one instance of a much larger problem, that of systems composed of various subsystems, which are at widely varying levels of development. This situation will always exist to some degree. It is just that at certain periods of time the gap between the levels of development is particularly great. This is one such case. The last decade of the 19th century was one of those periods of rapid technological change in which there were large gaps between systems, even those that were closely related or belonged to the same larger system. Such arrangements represent a "logistics nightmare" to borrow a phrase from Van Creveld.¹⁷ Prussian planners were faced with a dilemma. Vital logistics functions had to be performed. The system in place to perform these functions consisted of subsystems, some of which were advanced and efficient, while other subsystems were less advanced and in some cases obsolescent and inefficient. Further, the means to improve the obsolete portions was not readily available without major structural and operational changes. This problem was further compounded by the fact that, because of the wide technological gap, many of the various subsystems no longer complemented one another.

In such a case, what does one do? In the near term at least, one uses what is available and makes corrections as necessary. This is not done because it is the most desirable choice, but rather because it is the only choice. This was the situation in which Prussian war planners found themselves. In the next section I will discuss some of the consequences of this, as well as discuss some factors relating to how the Prussians found themselves in such a situation.

Benefits of Railroads

The military use of railroads gave the Prussians certain advantages that they would not have had otherwise. These advantages were numerous, but can generally be divided into four broad categories. These were (1) strategic/operational mobility, (2) ability to move large quantities of men and supplies, (3) speed, and (4) predictability. Being almost exclusively a land based power, these factors were to influence both operational and logistical planning to a greater degree than almost any other technological innovation.

Being primarily a land power, railroads gave Prussia for the first time a viable means of strategic and operational mobility. Prior to this, mobility was limited to the rate of march of men and horses. For a nation facing Prussia's geographic and strategic situation, this new found mobility offered the opportunity for victory, or at least survival, against opponents who were potentially more numerous and able to attack on more than one front.

Not only did the railroads provide new opportunities for mobility, they were also able to transport large numbers of men and

large quantities of supplies without tying up a large number of troops to do so. As mentioned earlier, an entire corps could be transported along one rail line using fewer railroad employees than would be found in one infantry company. This was a tremendous savings in manpower and horsepower.

In addition to transporting large quantities of men and matériel, railroads are well suited for heavy and bulky cargo. This made them excellent transportation platforms for ammunition, explosives, and fodder. Even today, with the possible exception of ships, railroads remain, mile-for-mile, the most efficient and cost effective method of transporting large, bulk cargo.

Railroads also enabled the Prussians to move men and supplies more rapidly than ever before. The speed or rate of march for men or horses are measured in kilometers per day. Four horses could move a ton of cargo 10, perhaps 20 kilometers per day. On the other hand, railroads could move 60-100 tons of cargo this same distance in 20 minutes. Trains measured their speed in kilometers per hour. They could regularly move cargo at 60 to 70 kilometers per hour. As Arden Bucholz points out, by 1900 trains were operating at these speeds, and it would not be until after World War II that significantly faster trains would regularly appear.¹⁸

The final advantage provided by the railroads was that of predictability. When compared with men and horses marching on unpaved and often muddy roads, railroads were fairly predictable, when it came to delivering cargo to a given place at a given time. Track was generally able to lift armies out of mud and move them along prepared

paths at regular speeds. In fact, regular rates of travel and predictable departures and arrivals are a requirement for the operation of a successful railroad system. Without this a railroad system would deteriorate into chaos.

The regularity and predictability of railroads gave war planners something they always desired: realistic planning factors and time tables. Railroads, while not without their faults, have much more predictable movement tables than marching men and horses. This fact did not escape war planners. Bucholz observed, "Railroads were the only functioning part of the war plan that could deliver continuous, reliable, and predictable levels of performance."¹⁹ While Bucholz may have overstated the case, his point is well made. By the standard of the late 19th and early 20th century, trains were more predictable over significant distances than marching men or horses could ever hope to be.

Limitations of Railroads

Railroads were a great innovation in military transportation. As such, they were also a tremendous innovation in logistics. As John Lynn reminds us, "While the question of transportation is not the sole issue at state in studying logistics, it is basic."²⁰ This is especially true in Central Europe, where almost all movement and logistics are tied to land transport.

While railroads are an extremely valuable tool, like all systems they have their limitations. I have grouped these limitations into four general categories. There are (1) rail movement is tied to rails, (2) rail movement is not a particularly flexible mode of transportation (3)

minor problems in one part can throw off the timing of the entire system, (4) railroads are resource intensive to build, maintain, and operate. Each of these limitations influences the way the system operates, and must, or at least should, be taken into account by all war planners.

It goes without saying that railroad movement is tied to rails. Where there are no rails, trains cannot go. This is significant when planning the use of railroads and is the reason they can normally only be used for strategic and operational movements. Serviceable rails seldom extended beyond the rear of the corps or division area. Consequently, railroads can rarely be used to support tactical movements. Also, in order to use railroads on a deployment, they must be planned where rails already exist. Armies can lay and repair track, however, this is a time consuming process. For rapidly moving operations it is usually impractical.

Planning to use railroads in enemy territory also presents a problem, since retreating armies frequently destroy key railroad bridges, junctions, and sections of track. Because of this, the planned use of railroads beyond ones own territory is problematic. This fact can limit the use of railroads for strategic mobility, one of the main reasons for which railroads were developed. This is a dilemma for railroads and one which they can never completely escape.

Being tied to rail, in addition to several other factors, means that railroads are not especially flexible systems. They cannot be easily redirected on short notice. This is partly the result of being tied to rails, partly a result of the detailed timing needed to make the

system work, and partly the fact that trains tend to be long and most cars are not capable of self-locomotion.

Since numerous trains must use the same tracks, bridges, junctions, and stations during a given period of time, reprogramming a particular train or series of trains has an impact on a whole system. Likewise, reprogramming an entire line to use another line is a time consuming and disruptive process. Part of this is due to the fact that trains, unlike wagon or vehicle convoys, cannot easily be broken apart and fed into other routes. Trains do not necessarily have to be long, however in order to have an efficient balance between locomotives and loads pulled, one locomotive will normally pull a number of cargo cars. The number of cars in a particular train will be governed by a number of factors including destination, type of cargo, and the military requirements. Most railroad cars are not capable of self-locomotion. They require locomotives to move them. It is true that a particular train may be broken apart and moved; however, this requires additional locomotives and is a time consuming process.

All of these factors contribute to the third limitation of railroads, the fact that problems in one part of the system can throw off the timing of the remainder of the system, frequently throwing the whole system into temporary chaos. This problem is not unique to railroads. It is nevertheless a common characteristic of systems that rely on detailed timing and the sharing of production mechanisms (i.e. track). The result being that delays, damages, or problems restricted to only one portion of the system can have profound effects on the entire system.

The Prussians had ample experience with this problem in 1864, 1866, and 1870. In each case increased traffic, delays, the rerouting of traffic, and delays in off loading contributed to the significant disruption of efficient rail operations. The rail system eventually recovered and the military was successful in its operation. Still, it must be remembered that each of these campaigns were concluded fairly quickly. In 1914, against more determined and numerous opponents, the limitations of the rail system were not so easy to overcome.

The final limitation to the use of railroads is that they are resource intensive. This is true in regards to developing, maintaining, and operating the system. Railroads were at that time both manpower and natural resource intensive. As stated earlier, by 1907 the German railroad and telegraph service was the largest employer in the country. At the same time the railroad was one of the nation's largest consumer of steel, coal, and lumber. A fairly advanced industrial capacity was needed to sustain a railroad. This helps to explain why railroad development was linked with industrial development. Nations without substantial heavy industry usually do not have extensive rail networks.

The fact that railroads require large amounts of manpower and resources may not be a problem in and of itself, however, during wartime or other periods of intense resource competition, this could become a problem. Railroads must compete with other parts of the war machine for men, steel, coal, lumber, etc.. During the short conflicts of 1864, 1866, and 1870-71, this problem did not develop. In 1914 the conflict was much larger, and the demands on the whole industrial system much greater. While conflicting requirements for resources is nothing new to

waging war, as all subsystems of the war machine began to compete for a narrowing range of resources (e.g., steel, coal, lumber, men, etc.), the industrial base strained to support all requirements.

The Link with the Supply System

Railroads greatly enhanced Prussia's ability to move men and supplies from one part of the country to another. At some point though, the rails ended and supplies and men had to move forward by other means. The end of the rails were commonly called railheads, although railheads exist at many other places than at the end of a line. The most forward railheads were normally located behind the field armies. In some exceptional cases, rails extended into corps or divisional areas.

Once supplies were off loaded at the railheads, it was the responsibility of the field armies to move them forward. With a few exceptions, the heavy supply companies had only draft horses and wagons to move supplies. This system did not change throughout the period of this study, and in fact remained in place in the German Army throughout World War II.²¹

The problem of transferring supplies from one transportation mode to another is always a challenge. When the various modes are relatively compatible, at least in the type, size, and configuration of the loads they can carry, this problem is much easier. When there are wide disparities between the modes of transportation, the problem is more difficult. This was the case with railroads and horse drawn wagons.

While it is possible to think of modes that are less compatible, railroads and horse-drawn wagons are radically different types of systems. They belong to different eras, the railroads to the industrial era, while horses and wagons are from the preindustrial era. In addition, their capacities are widely different. A wagon pulled by four horses could carry one ton of cargo. A train consisting of 60 cars could easily carry 60 tons of supplies, and likely more. Under these circumstances, delivering even 60 tons of cargo would require the equivalent of 60 wagons and 240 horses. This was about equal to the total number of supply wagons available to a corps in 1914. Yet by 1914 standards, 60 tons was less than 25% of a corps daily requirements. Even by the standards of 1870, this was only about half a corps' daily requirements.

Under such circumstances supply wagons would likely have to make several trips to and from the railhead just to keep a corps, or any other type of unit, supplied with its daily requirements. For a stationary unit a short distance from its railhead, this might be possible. When units were far from their railhead, or on the move, this was all but impossible. When supply wagons could not keep up with the deliveries made by the railroads there were two consequences: supplies backed up at the railhead and units did not receive the supplies they needed. Neither situation is desirable. Describing the first of these consequences, Van Creveld writes, "congestion forced supplies to be unloaded wherever labour and space were available, which was often in stations far to the rear."²² As railheads became congested, supply

trains were unloaded farther and farther from the units that needed the supplies.

The second consequence, that of units not receiving what they needed, is even more serious. Armies require supplies in order to fight. If deprived of these supplies long enough, they lose the ability to fight. Armies can often make up some of these shortfalls through local or self-supply. As consumption requirements became greater and more diverse, this is increasingly difficult to do. Also, this takes soldiers and other resources away from their primary functions of fighting the enemy. Armies usually resort to self-supply out of necessity, just as the Prusso-German armies of 1866, 1870-71, and 1914 did.²³ The return to self-supply demonstrated the ultimate failure of the supply system to perform its basic mission, that of getting supplies forward to the units that needed them.

Logistics Shortfalls

To determine whether or not the Prusso-German logistics system failed is not as simple as it might sound. Failure, just like success, is rarely absolute and most often measured in degrees. Also, to pronounce something a failure requires look at the end result of the overall organization. Before pronouncing the Prussian logistics system a failure, one must ask how much the victories of 1864, 1866, and 1870-71 owed to the logistics system versus how much the defeat of 1914-18 owed to the logistics system.

Unlike some writers, I am not prepared to pronounce the system a total failure. At the same time I am prepared to say that it did have

some serious shortcomings and that at times failed to accomplish its mission. Shortly I will discuss how much these failures were the result of the operation of the logistics system, versus the nature of the missions they were expected to execute.

The shortcomings of the Prussian logistics system were conceptual, structural, and operational. For ease of explanation, however, I have decided to discuss them in four general areas. These are (1) prior planning, (2) comparability of component parts, (3) ends, means, and will, and (4) maximum efficiency. Explaining these will give some insight into the failings of the logistics system.

The first question that arises is how much forethought and planning did the Prussians give to logistics? In the area of railroads, the Prussian's plans were exhaustive. Military Travel Plans (MTPs), the basis of all wartime movement, were worked out years ahead of time. Each year they were tested in staff exercises, maneuvers, railroad planning exercises, and communications exercises. Plans were adjusted yearly, based on the results from these exercises, in addition to changes in technology, equipment increases, and track layout. Not a year went by that Prussian war planners did not pay close attention to the capabilities of the railroads.

Since Prussian war plans were built around the rapid strategic movement of men and matériel, the railroads were critical. Whether or not the railroads were the central or driving factor in Prussian war planning is a topic worthy of debate, however, it is beyond the scope of this study. What is clear is that the Prussians closely studied,

planned, and coordinated the use of railroads for their wartime operations.

How much attention was given to the rest of the logistics system, particularly supply and transportation operations forward of the railhead? Surprisingly, the answer seems to be very little. Clearly this aspect received far less attention than did railroads. Commenting on this Holger Herwig states, "Logistics received scant attention: Schlieffen apparently expected troops to live off the land."²⁴ He further presses his point by highlighting the total lack of preparedness in procuring and planning to move commonly used military supplies.²⁵

Herwig's position may be somewhat overstated to make a point, but his general view is also supported by Addington, Bucholz, Lynn, and Van Creveld. Many explanations for this are given. It is not possible, nor even desirable to explore all of these in detail. Still, it is important to note a few points. Clearly the Prussians, and later the Germans, had some interesting and uneven ideas about the importance of technology. Likewise, the emphasis on operational planning and the need for a short, decisive war shaped logistics planning. Another insight is provided by Thomas Adriance when he writes, "In both wars (1866 and 1870-71) they had encountered nagging difficulties in bringing up supplies, but the campaigns had reached successful conclusions before the faults of the system had taken their toll."²⁶ The fact that the Prussians had been able to win, and win consistently with the logistics system they had surely did something to reinforce their belief that they would win again.

None of these is a complete explanation for the lack of prior logistics planning on the part of the Prussians. I am doubtful that there is one explanation. What is clear is that except for the railroads, no aspect of the supply and transportation system received the attention necessary to prepare it for a 20th century war.

As I mentioned earlier, the Prussians had compatibility problems between their two primary modes of transportation: railroads and horse drawn wagons. Not only did these two modes represent different eras and ideas about war, their capabilities and capacities were vastly different. While railroads had their problems, on an average day two or three trains of 60 cars each could deliver more supplies than an entire army's supply companies could hope to move in twice that time. When it is remembered that up to five lines might support one army, the magnitude of the problem becomes obvious.

To use an example, the transfer of supplies from the railroads to the field armies was like a fire hose being reduced to a garden hose. The point of transfer could not stand the strain. Describing this Van Creveld writes,

In part, this was due to the inherent limitations of a system of supply based on the unfortunate combination of a technical means of one age—the railways—with those of an earlier one. It is no accident that the worst difficulties occurred at the transfer points from one system to the other, i.e. at the unloading stations.²⁷

This incompatibility plagued the system throughout the period. The willingness of the Prussians to embark on a 20th century war with such a transportation system was already an invitation to a logistical shortfall.

The third shortfall was a failure to balance ends, means, and will. Commenting on this Dennis Showalter writes, "The essence of strategy is the calculating of relationships among ends, means, and will. Let the process of the calculation obscure the value of the relationship, and the result is not bad strategy, but no strategy."²⁸ Logistics represents the "means". If the means are not in proper relationship with the ends to be achieved and the will to do it, then at best one has a flawed strategy. In the case of Prussia, by 1914 if not earlier, this was the exact situation. Prussia had a strategy, but her logistics organization was so much out of line with the other parts, that its effectiveness was seriously questionable. Describing the situation Holger Herwig writes, "The hard reality was that Germany embarked upon a war of total mobilization with the tools of the nineteenth century: men and horses. Strategic goals and available resources were in disharmony."²⁹

In other words, Germany embarked on an industrial war with a logistics system whose weakest links still belonged to the agricultural age. Even if it had functioned at its peak capacity, it is doubtful that the logistics system of 1914 could have successfully supported its war machine. In fact, the logistics systems of 1864, 1866, and 1870-71 had never really supported their armies. The shortness of the conflict made this unnecessary. This helped to produce an army that placed little importance on its logistics and a logistics system that had never been tested. The logistics system of the Prusso-German Army had not been forced to reform itself based on its wartime performance. The result was a logistics system completely out of touch with the

requirements of the army it was to support. The railroads were an exception to this, but they were only one part of a complex puzzle.

The final shortfall of the Prussian-German logistics system, and the army as a whole, in the period just prior to the First World War was to assume that everything functioned at maximum efficiency. Clausewitz had written about friction and Moltke had always displayed a healthy skepticism about the ability of systems to function without serious flaws. Still by about 1905 at the latest, Prussian war planning took on an optimistic tone. It was not optimistic in the sense of the task it faced, but rather in the belief that with proper planning, war plans could be executed like clockwork. Dennis Showalter writes, "In other words, German military planning incorporated reasoned judgement of the German military requirements and prospects. It might stress the balance between means and ends to the limit, but never systematically exceeded them as a first choice."³⁰

This stressing the balance "to the limit" might be questionable under any circumstances, however, considering the situation with the logistics system, it was clearly unwise. The result was that the logistics system was expected to perform well beyond its capabilities. The folly of this was manifested in the performance of the supply and transportation systems not only in 1914, but also previously in 1864, 1866, and 1870-71.

The situation of the Prusso-German logistics system going into the Great War was one of inadequate prior planning; various parts almost incompatible; a misalignment of ends, means, and will; and a system

expected to function at maximum efficiency. It is no small wonder that the logistics system failed to perform up to the needed requirements.

A Complex Puzzle

The railroads had a tremendous impact on Prussian logistics. This is particularly true for the strategic aspect of logistics. Railroads enabled the Prussians to move men and matériel at speeds and in volumes far superior to those of her opponents. With its careful planning and management of the railroads, the Prussians changed forever the nature of strategic movements. At the same time I argue that the railroads had little useful influence on tactical logistics. Forward of the railhead the average soldier would have seen few benefits from the railroads. Why is this? The railroads were caught in what I will call a "complex puzzle syndrome." They were part of a complex operation the logistics system. As such they were able to solve their portion of the puzzle, but had few effects on the rest of the system. No matter how efficiently the railroads might deliver men and supplies, and at times this was not efficient either, they could do nothing to move cargo beyond the railhead. Forward of the railhead the Prussian Army moved by men and horses.

It can even be argued that the railroads made the tactical movement situation even worse than it would have been otherwise. Over time the railroads had become more and more capable of delivering supplies, while the horses and wagons of the heavy supply companies remained unchanged. The army might increase the number of horses and wagons, but their technical efficiency remained the same. The result

was that with each successive war, more and more supplies backed up at the railheads behind the field armies. This was not solely the fault of the railroads or the supply companies, but a failure of the overall system.

During this period the railroads saw many improvements, most due to improvements in technology. These allowed for more efficient operations by providing larger cars, more powerful locomotives, higher track utilization, greater speed, etc.. While the railroads became more efficient, the horse and wagon system remained almost the same as they had been 100 years previously. A part of the system had improved, but the overall output of the system remained unchanged.

The Prussian logistics system had failed to show proportional improvement throughout all its parts. The railroads were a quantum leap forward for supply and transportation operations. Railroads were, however, only one part of the system. Without some type of proportional improvements in efficiency in the other parts of the system, it was unlikely the overall system would improve. This brings us back to Showalter's earlier comments about the value of relationships within a system. If the relationships among the elements of a system become obscured, then the system fails to function properly.

In essence the Prussians put too much emphasis on railroads in relation to the emphasis they gave to the rest of the logistics system. This does not necessarily mean that they paid too much attention to the railroads, but rather too little to the rest of the system. The result was a system incapable of performing its mission.

The ultimate purpose of a logistics system is to get supplies and other services to the soldiers who need them. In most cases this means delivering them to combat soldiers in the forward area. Using such criteria the Prussian logistics system was not a overwhelming success. The system had serious flaws that reappeared over and over again. While the Prussian-German logistics system was not the sole source of its defeat, it did little to contribute to its chance of victory.

In my final analysis I would say that the railroads generally worked well. They were not without their problems, especially during the initial phases of mobilization. When compared with other aspects of the logistics system, however, they performed well. Yet, by themselves the railroads promised little chance of success. The irony is that the Prussian-German military, which applied so much systematic thought to many areas, did not do so to logistics. Logistics were treated as an afterthought, and likewise functioned as such. The railroads served the Prussians well, but in the end they could not overcome the general unpreparedness of the logistics system.

CHAPTER 5

CONCLUSION

This study set out to investigate the logistical impact of Prussia's use of railroads for strategic and operational mobility. The conclusion is that while the railroads had a noticeable influence on Prussian logistics, they did not significantly improve the general performance of the system. This is based on the fact that the ultimate measure of a logistics system is its ability to deliver supplies and services where they are needed. For the Prussians this meant delivering supplies to the armies operating in the forward area. Using this standard, the system did not perform well.

The problems with the Prussian logistics system were not due to any one shortfall, but rather the performance of the complete system. The most serious systemic problem was that of distributing supplies, a problem not unique to the Prussians. The transportation system in the Prussian Army had two primary modes; railroads and horses. Railroads were a fairly advanced and efficient system, while horses and wagons on the other hand were products of a different era, and were much less efficient. It is fair to say that by the early 20th century, while railroads met Prussia's strategic and operational mobility requirement, horses and wagons no longer provided adequate tactical mobility.

It is not enough, however, to say that all of Prussia's logistics problems were caused by her reliance on horses for tactical

transport. Horses have their inherent limitations. Their suitability for supporting large 20th century armies may be questionable, however, their use was one of necessity. When one considered the state of transportation development in the late 19th and early 20th century, clearly certain "technological gaps" existed. From the military standpoint, the most serious was that of a suitable system to move supplies once they had been offloaded from the trains. Because motor vehicle technology and production in Prussia/Germany (and the rest of the world also) was not sufficient to support their needs, all armies still relied on horses and wagons for most of their tactical transportation requirements.

Prussia's logistical problems were therefore not unique, nor due to the inherent limitations of horses, but rather an inability to balance the strengths and weaknesses of the subsystems that composed the logistics system. Railroads were fairly efficient at moving large volumes of supplies from one part of the country to another. At some point, however, the rails ended. From this point forward horses and wagons had to move the supplies. These were neither numerous enough nor especially efficient at moving large quantities of supplies, particularly in support of armies on the move.

In such a system the key to success is to understand the strengths and weaknesses of the component parts, and to develop a strategy to capitalize on the strengths, while overcoming or working around the weaknesses. It must be remembered that the ultimate measure of success for a logistics system is its end product: getting supplies

to the soldiers who need them, when they need them. The efficient operation of a particular subsystem or component part, while not irrelevant, is not the measure of success for the system.

This was the mistake the Prussians made in regard to railroads. The Prussians devoted tremendous amounts of time and effort to planning the use of railroads. Every year they carefully studied their railroad system and made adjustments and corrections where needed. As pointed out earlier, by 1900 the use of railroads was the most comprehensive part of the war plans.

At the same time the tactical movement of supplies and equipment received only modest concern. The size, structure, and employment of the heavy supply companies had not changed since 1870, although the quantity of supplies consumed by field armies had risen by 500%. The railroad system that went to war in 1914 was a much improved system over that used in 1870. At the same time the heavy supply companies had remained largely unchanged for one-half of a century.

While the Prussians devoted a great amount of attention to the railroads, by the early twentieth century their logistical problem was not strategic or operational mobility. Their problem was the tactical distribution of supplies. Yet, while the Prussians continued to modernize their railroads, they devoted few efforts to improving tactical transportation systems. Their error was a failure to realize that no matter how efficiently the railroads could deliver vast amounts of supplies to the railhead, all of this did not effect getting supplies forward to the armies that needed them. The railroads stopped where the rails ended. The mission of the logistics system did not.

The Prussians had three systemic problems. One was the failure to appreciate that improvements in one part of a system are no guarantee of improvements in other parts of the system. The second was a failure to understand that an improvement in one part of a system is no guarantee that the overall efficiency of the system as a whole will improve. The third problem was a failure to see that the end product, or total performance of a system is the measure of a system.

Attempting to solve their mobility problems with railroads, the Prussians committed the error of the "compartmented solution." This is the failure to understand, that in a complex system, subsystems, while linked to one another, have limited influence on the other parts of the overall system. In other words, improving one part of a system is no guarantee of improvements in other parts of the system. This is exactly what happened to the Prussians. They continually improved the efficiency of their railroads, but this had little effect on the real problem; the tactical distribution of supplies.

The Prussians had almost reached a point of diminishing returns with their railroads. It was not that the railroads could not be further improved, but rather that any significant improvement in the overall logistics system was dependent upon subsystems other than the railroads. As for general logistical efficiency, the Prussians would have done better to devote more efforts to the tactical portion of their transportation system. Here was the chokepoint. Until they developed more effective methods to clear the railhead, supplies would continue to pile up just as they had in 1864, 1866, and 1870-71. The railroad went

far in solving Prussia's strategic and operational mobility problems, but it could not solve her tactical mobility problems. A failure to come to terms with this contributed to Prussia's logistical shortcomings.

The most significant of the three problems for the Prussians was a failure to see that the goal of a logistics system is the delivery of supplies and services where they are needed, when they are needed. Logistics is not only concerned with process; but end product as well. How well any particular component of a system functions is important, still it is not an end by itself. Prussia's failure was in not seeing that the timely delivery of supplies and equipment was the measure of success. That is the whole purpose of a logistics system. How many tons of supplies the railroads could deliver to any given railhead, while not totally irrelevant, was not the measure of success. This type of thinking led to the situation where tons of supplies stacked up at the railhead because the railroad was "too efficient" for the other parts of the transportation network.

The best chance of success for the Prussians was a comprehensive review of the purpose of their logistics system and the means they had at hand to accomplish this purpose. This type of approach would lead to a systemic, balanced approach that carefully matches goals with the means to accomplish them. Logistics is not just a collection of its component operations. One must always look towards the end product. Once this is done, the means can be focused towards achieving the goal. To ensure the best efficiency for the entire system, the operations of the component subsystems must be adjusted so that they complement one

another. When various subsystems are at widely separated ends of the technological spectrum, this is not easy to do. The Prussian's experiences with railroads and horse transport are a good example of this dilemma. If not done, however, and each system (or subsystem) is allowed to operate at its own self-determined efficiency, then the total efficiency of the system will suffer. This was Prussia's situation. The railroads delivered supplies efficiently, the horses and wagons distributed them to the best of their abilities, but the army frequently went without the supplies it needed. Besides this, supplies already delivered by the railroads often spoiled at the railhead, thus wasting not only the supplies, but the efforts expended to deliver them that far. The end product for Prussia was a system in which the distribution of supplies to their final destination was slow, irregular, and wasteful.

For all armies during this period the tactical movement of supplies was a problem. The technology needed to overcome this problem was not readily available and the management tools available to do so were at best imprecise. The widespread availability of motor vehicles later in the 20th century would put tactical transport on a more even footing with the railroads. These, nevertheless, had their shortcomings too. While motor vehicles would alleviate one set of problems, they would create new ones.

The world has changed a lot since 1914. With this in mind, what logistical lessons can we learn from Prussia's experience with railroads? I see three broad lessons we can learn: (1) railroads, if

managed properly, still remains an important mode of strategic, operational, and even tactical mobility for personnel and certain types of cargo, (2) do not expect one system to remedy the shortfalls of another distinct system, even when the two systems are similar or connected by their operations, and (3) logistics is, and must always be viewed as a whole process directed towards an end goal. While the first point, whether one accepts it or not, somewhat speaks for itself, the other two are problems that all of us see regularly in logistics, as well as in other areas. This is because they are systemic problems relating to the management of technological systems. How well we, like the Prussians, succeed in overcoming these types of problems will largely decide the success of our logistics operations. While logistics is not an end in itself, the success of armies in properly executing their logistics mission is a strong indicator of their ability to fight successful wars.

ENDNOTES

Chapter 1

¹John A. Lynn, ed., Feeding Mars: Logistics in Western Warfare from the Middle Ages to the Present (Boulder, CO: Westview Press, 1993), vii.

²Carl von Clausewitz, On War, ed. and trans. by Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 119.

³Arden Bucholz, Moltke, Schlieffen and Prussian War Planning (Oxford: Berg Publishers, 1991), 39.

⁴Ibid.

⁵Hajo Holborn, "Prusso-German School: Moltke and the Rise of the General Staff," in Makers of Modern Strategy, ed. Peter Paret (Princeton: Princeton University Press), 281.

⁶The Economist Atlas (New York: Henry Holt and Company), 197.

⁷Ibid., 32.

⁸Ibid., 32.

⁹Ibid., 19.

¹⁰Dennis E. Showalter, Railroads and Rifles: Soldiers, Technology and the Unification of Germany (Hamden, CT: Archon Books, 1975), 26.

¹¹Ibid.

¹²B. R. Mitchell, European Historical Statistics 1750-1970 (New York: Columbia University Press, 1978), 4.

¹³Ibid.

¹⁴Ibid.

¹⁵Ibid.

¹⁶Gunther E. Rothenberg, "Moltke, Schlieffen, and the Doctrine of Strategic Envelopment," in Makers of Modern Strategy, ed. Peter Paret (Princeton: Princeton University Press, 1986), 315.

¹⁷Ibid., 85.

¹⁸Ibid., 85-86.

¹⁹Ibid., 87.

²⁰Ibid., 89.

²¹Ibid., 90.

²²Ibid.

²³Holborn, Prusso-German, 290.

²⁴See Franz Uhle-Wettler, "Auftragstaktik: Mission Orders and the German Experience," in Maneuver Warfare: An Anthology, ed. Richard D. Hooker, Jr. (Novato, CA: Presidio Press, 1993), 236-245.

²⁵Helmut Graf von Moltke, On the Art of War: Selected Writings, ed. Daniel J. Hughes trans. Harry Bell and Daniel J. Hughes (Novato, CA: Presidio Press, 1993), 9.

²⁶Holborn, Prusso-German, 289.

²⁷Arden Bucholz, Hans Delbrueck and the German Military Establishment: War Images in Conflict (Iowa City: University of Iowa Press, 1985), 69.

²⁸Showalter, Railroads, 39.

²⁹Walter Goerlitz, History of the German General Staff 1657-1945, trans Brian Battershaw (New York: Frederick A. Praeger, 1953), 130.

³⁰Moltke, Art of War, 13-14.

³¹Bucholz, War Planning, 315.

³²Ibid., 183.

³³Dennis E. Showalter, Tannenberg, Clash of Empire (Hamden, CT: Archon Books, 1991), 117

³⁴Holborn, Prusso-German, 287.

³⁵Ibid.

³⁶Ibid., 288.

³⁷Showalter, Railroads, 19.

³⁸Mitchell, 315.

³⁹Ibid.

⁴⁰Showalter, Railroads, 27.

⁴¹Bucholz, War Planning, 39-40.

⁴²Ibid.

⁴³Jay Luvaas, The Military Legacy of the Civil War: The European Inheritance (Chicago: The University of Chicago Press, 1959), 122.

⁴⁴Ibid.

⁴⁵Ibid, 123.

⁴⁶Francis A. Lord, Lincoln Railroad Man: Herman Haupt (Rutherford, NJ: Fairleigh Dickinson University Press, 1969), 35.

⁴⁷Ibid., 39.

⁴⁸Luvaas, 122.

⁴⁹Ibid.

⁵⁰Holborn, Prusso-German, 287.

⁵¹Showalter, Railroads, 21.

⁵²Bucholz, War Planning, 226-227.

⁵³Mitchell, 54.

⁵⁴Aktuell '92; Das Lexikon der Gegenwart (Dortmund: Harenberg-Lexikon-Verlag, 1992), 82-83.

⁵⁵Luvaas, 127.

⁵⁶P. D. Foxton, Powering War: Modern Land Force Logistics (London: Brassey's, 1994), 50.

⁵⁷Ibid.

⁵⁸Ibid.

⁵⁹Ibid.

⁶⁰Ibid.

⁶¹Lynn, 10-11.

⁶²Moltke, Art of War, 102.

⁶³Bucholz, War Planning, 148.

⁶⁴Ibid., 149.

⁶⁵Ibid., 41-42.

⁶⁶Showalter, Railroads, 47.

⁶⁷Thomas J. Adriance, The Last Gaiter Button: A Study of the Mobilization and Concentration of the French Army in the War of 1870 (Westport: Greenwood Press, 1987), 50.

⁶⁸Larry H. Addington, The Blitzkrieg Era and the German General Staff, 1865-1941 (New Brunswick: Rutgers University Press, 1971), 16.

⁶⁹Monique and Hans D. Dossenbach, The Noble Horse (New York: Portland House, 1983), 170.

⁷⁰Martin Van Creveld, Supplying War: Logistics From Wallenstein to Patton (Cambridge: Cambridge University Press, 1977), 110.

⁷¹Addington, 9.

⁷²Ibid.

⁷³Van Creveld, 84.

⁷⁴Addington, 9.

⁷⁵Ibid.

⁷⁶Lynn, 21-23.

⁷⁷Bucholz, War Planning, 162-63.

⁷⁸Ibid.

⁷⁹Ibid.

⁸⁰Van Creveld, Supplying War, 124.

⁸¹Ibid., 112.

Chapter 4

¹Lynn, 26-27.

²Ibid.

³Addington, 16.

⁴Michael Howard, The Franco-Prussian War: The German Invasion of France 1870-1871 (New York: Dorset Press, 1961), 82.

⁵Addington, 9.

⁶Howard, Franco-Prussian War, 82.

⁷James A. Huston, The Sinews of War: Army Logistics 1775-1953 (Washington D. C.: Center of Military History, 1966), 382.

⁸See F-M 9-6, Munitions Support in the Theater of Operation (Headquarters, Department of the Army, 1988), D-1 thru D-3.

⁹Huston, 385.

¹⁰Ibid, 399.

¹¹Van Creveld, 182.

¹²Lynn, 10.

¹³Ibid.

¹⁴Mitchell, 278-279.

¹⁵Holger H. Herwig, "Strategic Uncertainties of a Nation-State: Prussia-Germany, 1871-1918", in The Making of Strategy: Rulers, States, and War, ed Williamson Murray, MacGregor Knox, and Alvin Berstein (Cambridge: Cambridge University Press, 1994), 268.

¹⁶Martin Van Creveld, Technology and War: From 2000 B. C. to the Present, (New York: The Free Press, 1989), 231.

¹⁷Ibid.

¹⁸Bucholz, Prussian War Planning, 148.

¹⁹Ibid., 56.

²⁰Lynn, 13.

²¹See Addington, 40-41.

²²Van Creveld, Supplying War, 98.

²³See Lynn, 19.

²⁴Herwig, 275.

²⁵Ibid., 274.

²⁶Adriance, 50.

²⁷Van Creveld, Supplying War, 105.

²⁸Showalter, Tannenberg, 34.

²⁹Herwig, 267.

³⁰Showalter, Tannenberg, 106.

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